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Object introduction, exploration, and play behavior in Black-throated monitor lizards (Varanus albigularis albigularis)

Jennifer Diane Walton Manrod

To the Graduate Council:

I am submitting herewith a thesis written by Jennifer Diane Walton Manrod entitled "Object introduction, exploration, and play behavior in Black-throated monitor lizards (Varanus albigularis albigularis)." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ecology and Evolutionary Biology.

Gordon Burghardt, Christine Boake, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Object Introduction, Exploration, and Play Behavior in Black-throated Monitor Lizards (*Varanus albigularis albigularis*).

A Thesis
Presented for the
Master of Science Degree
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Jennifer Manrod
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DEDICATION

This thesis is dedicated to my husband, Matthew Manrod, great supporter and friend, my parents, Robert Walton and Gwen Walton, wonderful role models and guides, and the rest of my family, friends and coworkers, for always encouraging me, believing in me, and inspiring me to reach for the stars, achieve my goals, and accomplish feats I could have never imagined.

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ABSTRACT

It is widely accepted that providing stimulus enrichment and opportunities to play is an important part of the development and maintenance of behavior and well-being in mammals. However, extending this idea to non-avian reptiles has barely been explored. Observations reported by scientists, zookeepers, and others, however, have suggested that non-avian reptiles can and do perform some form of play and exploration with novel objects and may benefit from enriched environments. Varanids display several advanced mammalian-like characteristics (i.e. physiology, life history, and prey discrimination) compared to other reptiles, and it is plausible that higher cognitive behaviors are also present. It was hypothesized that play and exploratory behaviors would be exhibited in the these trials and that the monitors would react differently to each stimulus.

This study, based on systematic videotaped trials, analyzed the behaviors of eight juvenile Black-throated monitors, *Varanus albigularis*, in response to an enriched environment. Two objects (food ball and food tube) and one social stimulus were introduced. The food ball allowed the monitors to see and smell, but not attain, the prey while the food tube allowed the monitors to attain the prey through hinged doors. In the social introductions the monitors could see and smell, but had no physical contact with, a conspecific placed in their home enclosure.

After constructing a behavioral inventory based on the videotapes, the mean duration and mean occurrence of various state and event behaviors were analyzed. There were many significant differences in the amount and type of behavior patterns elicited ($p<0.009$) by the different types of stimuli introduced. Responses to the food ball exhibited the most change over time and primarily consisted of exploratory and play-like behaviors after the predatory responses decliined. However, this stimulus was presented the most times (10). Responses to the food tube were primarily predatory behaviors and the lizards showed learning in opening the tube and capturing the prey by the second trial. Finally the conspecific elicited social behaviors that were not seen in the other two treatments such as a rocking seesaw behavior. These results suggest these animals are interactive, discriminating, and exploratory.

This study provides further evidence for the need for more in depth enrichment, specifically object introductions, in captive non-avian reptiles. The responses seen in captivity can lead us to reassess behavior reported in wild monitors, as well as to look for more affiliative social behavior and novel foraging tactics. Due to the results of this and similar studies, serious consideration should be given to providing enrichment in captive squamate reptiles in general, and large long-lived species in particular.

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SECTION I: INTRODUCTION

To fully understand both the nature of this study and the impact it could have on current and future non-avian reptile captive environments, it is important to explore our past and current understanding of enrichment, exploration, and play.

Importance of Enrichment

History

In the past few decades there have been many studies on captive animals and their well-being. The impetus for this work derives from the increasing need to maintain captive populations of species threatened in their natural habitat, and a growing number of plans to re-introduce captive bred animals into the wild. Early attempts to improve captive conditions were based on increasing an animal's activity by increasing the size and enhancing the natural appearance of the enclosure (Hediger 1950). However, larger exhibits did not necessarily lead to greater activity or more normal/natural behavior. Hediger was one of the first to recognize that space was not the only problem with captivity. He summarized the biological problems of captivity into three groups: space, food, and the animal-human relationship (Hediger 1950). Various methods to reduce the effects of these problems, including increasing space, complexity, and variability were discussed. Specifically he proposed novel presentations of food to encourage natural foraging in order to minimize the stress of the captive animals (Hediger 1950, 1969). The amount of space, complexity, and variability provided by captive environment has been the focus of recent studies. This first form of enrichment, striving for naturalism, is seen in most modern zoos.

Though aesthetically pleasing to viewers, and more stimulating than enclosures of the past, "naturalistic" environments still may be predictable and boring to the animals. This applies especially to large and naturally wide-ranging animals (Burghardt 1996; Rivas and Burghardt 2002). The idea that changing the general appearance and size of enclosures could act as the only form of enrichment was illustrated in a survey of gorilla, *Gorilla gorilla*, and orangutan, *Pongo pygmaeus*, enclosures in forty-one zoos. Activity levels were measured and found to be most highly correlated with the number of animals present as well as the presence of stationary or temporary objects available. Specifically, both species' activity levels were correlated with the number of animals present. For gorillas, the availability of both stationary and temporary objects was also correlated with increased activity levels; orangutans were more active when stationary and movable objects were available. The size and construction of the enclosures were not correlated with activity levels (Carlstead 1996).

In general, "environmental enrichment" means providing a complex and diverse environment that increases the possibility that the captive animal will demonstrate more of its natural behaviors including finding food, establishing territories, building a nest, maintaining its physical condition, escaping

conspecifics, or hiding (Carlstead 1996). The first published recognition of the significance of enrichment was by Yerkes (1925) concerning nonhuman primates. Yerkes' discussion of enrichment was later greatly extended by Hediger (1950, 1969). The importance of the physical environment of animals in captivity, as well as the impact of management decisions and diet on the well being of animals, were the main premise of these early concerns. In the 1960's, the planning of zoo exhibits included not only the needs of the public but also the animals' natural history into exhibit plans (Kortland 1960; Reynolds and Reynolds 1965; Freeman and Alcock 1973). The 1980's saw substantial growth in the proliferation and sharing of environmental enrichment among animal caretakers. Before that time, many inventive enrichment ideas went unreported. These developments furthered both the acceptance and proliferation of enrichment (Shepherdson 1998; Mellen and MacPhee 2001)

Previous Studies and Definition of Enrichment

Hal Markowitz pioneered studies of enrichment and developed methods for enhancing the behavioral patterns of a variety of zoo animals. Markowitz' major premise was to provide animals some choices within their environment (Markowitz and Woodworth 1978; Markowitz 1982; Markowitz and Aday 1998). The idea of choice spurred many examinations of the predictable manner in which zoo animals are fed. One of the first studies in this area demonstrated that when given a choice between "working" for food and having food provided, many animals chose to work for their food (Neuringer 1969). This and more recent studies demonstrated the biological need for foraging and that denying an animal appetitive opportunities might be a source of frustration or stress (McFarland 1989; Carlstead et al. 1991; Shepherdson et al. 1993; Hughes and Duncan 1998; Shepherdson 1998).

Carlstead (1998) further explored the biological need for foraging or predation and the pitfalls of the typical feeding routine in zoos. She theorized that the zoo animals who are out of their natural environment, living in restricted relatively stimulus-poor surroundings, fed in a highly predictable manner requiring little to no effort to obtain food, will most likely develop stereotypies (Carlstead 1998; Mellen and MacPhee 2001). Some degree of control over the environment can be achieved by allowing a captive animal the opportunity to work for food. This is accomplished by providing more natural prey that takes more time to locate and consume (Kastelein et al. 1989), or by hiding food to encourage forage feeding (Kastelein and Weipkema 1989). Animals seem to benefit from seeing things change as a result of their actions and having some control over their environmental contingencies (Markowitz 1982).

Besides reducing the behavioral effects of a captive environment, some experiments report functional changes in brain anatomy as a result of rearing animals in environments of varying physical complexity. For example, rats reared in enriched environments (larger cages, larger groups, tunnels, nest material, and toys) have a higher cerebral cortex weight, increased number of glial cells, and increased dendritic branching in the visual cortex (Wurbel 2001). Behaviorally, animals reared in more complex environments exhibit higher motor activity and more exploration in a standard test situation. There were also possible

differences in emotionality that may enhance learning and the response in a novel situation. The environmentally facilitated development of neurons in the central nervous system has been theorized to explain the behavioral changes seen in enrichment studies. Such development is thought to enhance an animal's ability to cope with multiple and varied environmental challenges (Carlstead 1996). More recent studies, mostly in rats, have found that enrichment has additional effects on the brain including increased neurons and synapses, especially in the cortex and hippocampal regions that are associated with increased learning and memory (Wurbel 2001).

Although the possibility for increasing an animal's welfare through enrichment has been supported by these physiological studies, it is often difficult in most captive species to measure and quantify differences in physiology and in the brain without an inordinate amount of stress. Thus, in order to find the most effective enrichment plan in typical captive environments, behavioral indices have been used to assess the value of enrichment involving maintaining levels of movement, alleviating space confinement, and modifying deviant behavior (repetitive pacing, attempts to break confinement, resting or sleeping abnormally, engaging in destructive activity toward itself, keepers, or the enclosure) (Anderson and Wood 2001). Markowitz once described the overall definition of environmental enrichment as elements of the environment that measurably increase the animal's well-being. The main goal of enrichment is to provide captive animals with the physical, behavioral and psychological resources that will best compensate for the deficits resulting from their captive state (Burghardt 1996).

The recent discipline of environmental enrichment is an explicitly systematic, scientific approach to understanding and providing for the psychological and behavioral needs of captive animals. Combining recently derived knowledge from the fields of ethology, psychology, neuroscience, and applied animal science, this new discipline offers an alternative way of looking at the environments provided for captive animals. Today's enrichment techniques involve assessing an animal's natural and individual history, exhibit constraints, and providing species appropriate opportunities. It has recently been proposed that there is no single definition of enrichment (Mellen and MacPhee 2001). Instead it is suggested that enrichment can be re-defined for each species and perhaps different plans can be developed for each individual as well as different situations and desired outcomes (e.g., breeding success, increased activity, etc.). The most recent enrichment studies in captivity have been conducted not only in an attempt to alleviate abnormal behavior or inactivity, but to implement a concerted plan of action for captive management with measurable goals and results (Mellen and MacPhee 2001).

Object Introductions

The introduction of a novel object is one of the most common and cost effective methods of enrichment. In the past decade, much research has been done on the introduction of different objects and their effect on various species. Usually the choice of objects used is based on expense, ease in preparation,

durability, cleaning, and maintenance. Most object introductions and enrichment research has been on mammals, specifically non-human primates.

Recently, one of these studies not only explored the animals' response to different objects but also concentrated on the properties of the objects (Sambrook and Buchanan-Smith 1995). The study compared complex objects and objects that respond to the animal, in this case four species of guenon (*Cercopithecus*). The study species included five individuals of the Diana monkeys (*C. diana*), four Hamlyn's owlfaced monkeys (*C. hamlyni*), two de Brazza's monkeys (*C. neglectus*), and two Allen's swamp monkeys (*Allenopithecus nigroviridus*). The items introduced included simple objects (two yellow maracas, one with and one without contents) and complex objects (two white toy phones that had a rotating disc, sliding toggle, and a pad that played a tune when pressed, one functioning, one fused with glue). The results showed that responsiveness (functioning maraca and telephone) but not complexity (no preference between simple or complex) affected the interest an object held for this set of animals. This study showed that an object that an animal can control, and that responds to the animal in some way, is used by a larger proportion of animals and for longer periods of time than devices that do not respond. Complexity and responsiveness are only two of the characteristics recently studied. It has been found that continuing novelty and variability are also needed to increase exploratory behavior in animals (Mench 1998).

Additional studies have been conducted on a variety of other mammals. Most of this research is begun with specific goals, primarily the reduction or removal of sterotypies and other harmful behavior patterns. An example of a study that attempted to reduce the performance of a stereotypic behavior was recently conducted with captive common seals, *Phoca vitulina* (Grindod and Cleaver 2001). The enrichment technique that appeared to have the most impact on the seal's behavior was the fish pull (a fish attached to a pulley system). All the seals actively chased and competed for food presented in this manner. This encouraged not only feeding behavior, but also not overtly aggressive competitive interactions among the animals, which are often seen with the provision of supplementary resources (Chamove and Anderson 1989; Murray et al. 1998). Another enrichment item that gained much attention from the animals was the fish hidden in a bottle. The main goal was to occupy more time in feeding/foraging behaviors by the seals. A significant reduction in the performance of stereotypic circling behavior in three captive common seals was observed (Grindod and Cleaver 2001).

Comparative studies have also been completed on a wide variety of mammalian species. In a recent study, unusual because comparable experimental methods were used, various stimuli (objects, sound, and odors) were provided to four different captive species in an attempt to further understand the exploratory and play behaviors involved in enrichment (Lampard 2002). The species investigated were barbary sheep (*Ammotragus lervia*), plains zebra (*Equus butchelli*), oriental small-clawed otters (*Aonyx cinerea*), and collared peccaries (*Tayassu tajucu*). The specific enrichment included stationary and movable objects, food related olfactory stimuli, and predator-associated auditory stimuli. Through this extensive study it was found that both exploratory and play behavior increased during the novel introductions, while there

was a decrease in stereotypical behaviors across all species (Lampard 2002). Nonetheless, species differences occurred, and some were unexpected.

Glickman and Sroges (1966) conducted one of the most comprehensive studies of object exploration in a captive environment. Their study included 242 subjects representing over 100 different species including four non-avian reptile species. The exploratory behavior observed was subdivided into visual exploration and contact with a series of objects that included a water hose, wood block, and piece of metal chain. The data were compared and various trends emerged concerning the amount of exploration and the animals' habitat and behavioral adaptations. Non-avian reptiles were included in this comparative study of curiosity in zoo animals toward introduced objects (Glickman and Sroges 1966). An Orinoco crocodile (*Crocodylus intermedius*) was rated highest in response to an introduced object followed by three lizards, two of which were monitors. Overall, it was found that predatory species were the most likely to explore, while prey species were more cautious and tended to avoid novel stimuli (Glickman and Sroges 1966).

There has been considerable research on object enrichment in primates and mammals as seen in the examples above; however, there have not been many similar studies concerning birds or non-avian reptiles. Recently these two taxa have been gaining attention. One such study involved young Amazon parrots (*Amazona amazonica*). Although stereotypic behaviors, e.g. psychogenic feather picking, have been studied in domestic birds such as chickens, similar behaviors in wild species such as parrots have only recently been examined (Meehan et al. 2003). The subjects explored were sixteen Orange-winged Amazon parrots (*A. amazonica*) hatched in the animal colony at the University of California, Davis, from wild-caught pairs imported from Guyana. These individuals were separated into either a control or enriched group. Two categories of enrichment were used including physical enrichment and foraging opportunities. The physical enrichment included perching sites, climbing/swinging opportunities, and movable objects. The foraging opportunities included barriers that could be chewed, objects that could be manipulated through holes, edible and inedible material that had to be sorted, or food containers that had to be opened. A different combination of one foraging and one physical enrichment object was presented to each of the enriched individuals per week for 16 weeks. After 16 weeks, the control group (which had developed feather picking) was enriched and feather scores recorded for another 16 weeks during which re-feathering occurred. The feather scores represented the extent of feather picking and were quantified on a ten point scale, based on scoring the feather condition in five body areas. The data showed that providing an enriched environment, including foraging substrates and increased physical complexity, can significantly modify both the development and performance of stereotypical feather picking behavior by parrots (Meehan et al. 2003).

Although there have only been a few enrichment studies in non-domestic birds, as compared to mammalian studies, similar studies in non-avian reptiles have been even more rare. One well-documented and systematic study was conducted on a captive Nile soft-shelled turtle (*Trionyx triunguis*) at the National Zoo (Burghardt et al. 1996). Over several years this adult turtle was provided various objects including

balls, sticks, and hoses (all non-food objects) in an attempt to reduce self-mutilation behavior. Video analyses of these interactions helped to develop and establish various behavior patterns and indicated that the turtle was interacting with the objects and increasing its activity levels during the introductions. The level of self-mutilation behavior decreased greatly over many months of enrichment (Burghardt et al. 1996). This study established the possibility that enrichment could improve the conditions in captive non-avian reptiles.

Defining Behaviors Observed When Providing Enrichment

Criteria for Exploration and Play in Captive Animals

The discipline of enrichment is not only concerned with which objects to introduce but also how to define the behaviors observed during the enrichment. One of the most frequent responses to object introduction, so far documented mostly in mammals, has been the appearance of exploratory and play behavior.

Exploration

Both past and present studies have investigated exploratory behavior in captive animals. In the past, the main focus of discussion was the relationship between exploration and fear. One of the theories was that exploration occurred in the presence of a novel stimulus when both curiosity and fear/anxiety were elicited, thus defining exploration as a combination of tendencies to approach and avoid the novel stimulus. Another prevalent theory was a direct relationship between exploration and fear, stating that exploration occurred when a low amount of fear is elicited causing the animal to approach. However, if fear was high, the novel stimulus would only elicit avoidance behaviors (Russel, 1973).

In both past and present discussions, a common theme seems to be the difficulty in finding a uniform definition of the terms, such as exploration and play, used to describe an animal's response to a novel stimulus or environment. Over the last fifty years, the main debate has been the struggle to arrive at a universal theory for the motivation behind exploration. Overall, through past and present day studies, exploration has been mainly defined as those activities concerned with gathering information about the environment. Exploration is primarily considered an investigatory behavior (Burghardt 1984). In order to further define exploration, it was thought that the motivation behind the behavior must first be agreed upon. Recently it has been suggested that, "if a motivational force must be proposed it is sufficient to accept that, as indicated by studies of stimulus deprivation (Kish and Antonis 1956; Darchen 1957; Premack et al. 1957), animals seem to have a behavioral 'need' for sensory change that can be satisfied by exploratory responses" (Hughes 1997 p. 219).

Hughes defined exploration in two different terms, intrinsic and extrinsic exploration. Extrinsic exploration is stimulus driven and involved in experiments that present the animal with a choice, e.g., between familiar and novel environments. Intrinsic exploration is the behavior seen in novel object introductions. These intrinsic exploration behaviors seem to happen more frequently when the animal is healthy, well fed, and unstressed. These behaviors occur when the animal is presented with an object in a familiar environment and there is no apparent chance for habituation to occur before the trial or escape from the novelty during the trial. It involves exploratory acts that do not seem to occur in order to reach a particular goal, other than performing the acts themselves (Hughes 1997).

Exploration has also recently been investigated in terms of stress conditions and the resulting physiological changes that occur before, during, and after this behavior. It has been shown that glucocorticoid evokes the exploratory response in rats in novel, but not familiar environments (Greenberg et al. 2001). Further studies have shown that corticotrophic-releasing hormone also plays a role in enhancing the effects of novelty (Greenberg et al. 2002).

Play

The problem of defining behaviors that occur in object introduction research is further complicated in defining and identifying play and distinguishing play from exploratory behaviors. The manipulation of objects was once considered only intense exploratory action and rarely classified as play. It was later determined that during these enrichment sessions most early responses in the interaction are clearly exploratory and most of latter responses are clearly playful (Aldis 1975). Exploration can be summarized as 'what is this object?' while play follows exploration and can be summarized as 'what can I do with this object?' (Hutt 1970).

Most definitions of play serve only as a post hoc means of describing the behavior that the investigator is convinced is play. The surplus resource theory was applied to play and summarized by Burghardt in 1988. The main concept of this theory was that when other needs are met, play can be beneficial but it is doubtful that play originated in direct association with any long term or delayed benefits (Burghardt 1988). The many discussions, investigations, and evaluations of play in the literature have recently been reviewed and the result was a set of five criteria that aid in separating play from nonplay in all contexts and species (Burghardt 2001). These five criteria have been proposed useful in separating play from non-playful behavior in any species where it may occur:

1. **"Not Completely Functional":**

   Play behavior is not completely functional in the form or context in which it is expressed. In other words, the behavior includes elements or is directed toward stimuli that do not contribute to current survival.

2. **"Endogenous Component":**

Play involves phenomenon to which one or more of the following terms can be involved: spontaneous, voluntary, intentional, pleasurable, rewarding, or "done for its own sake."

3. **"Structural/temporal difference":**

Play is distinguished from the "serious" performance of other behavior in at least one respect; incomplete, exaggerated, awkward, or involving behavior patterns with either a modified form, sequence, or target.

4. **"Repeated":**

Play involves behavior that is repeated in similar, but not rigidly stereotyped, form during at least a portion of the animal's ontogeny. This particular criterion is important in distinguishing curiosity in response to novel stimuli from play actions following initial exploratory behavior.

5. **"Relaxed field":**

Play is only initiated when the animal is adequately fed, healthy, and free from acute or chronic stress.

Using these five criteria, play is considered to be "repeated, incompletely functional behavior differing from more adaptive versions structurally, contextually, or ontogenetically, and initiated voluntarily when the animal is in a relaxed or unstressed setting" (Burghardt 2001 p. 322).

It is important to not only record that play occurs but investigate the animals, environments, and developmental stages where play occurs comparing captive, wild, juvenile, and adult forms of this behavior. In general, play is more frequent in captive animals than in their free-ranging counterparts. The higher rates of play seen among captive animals are commonly attributed to unlimited food resources and the absence of predators. Captive animals have no need to flee from danger and a reduced need to search actively for food; therefore, play might be a captive animal's only means of staying fit and active (Thompson 1996).

Adult animals, in particular, seem to show more play in captivity (Fagen 1981). Fagen suggested that this might represent a reversion to a more juvenile state, since in captivity most of an animal's needs are provided for. Alternatively, he proposed that play in adult captives might provide a means of remaining in a healthy physical condition where opportunities for vigorous exercise are otherwise absent. Object play by adults consists of patterns from more than one type of behavior and is rarely mixed, although there is often repetition of particular behavior patterns. Carnivorous species from a variety of taxonomic groups incorporate elements of predatory behavior into play with objects. Adult object play, in captive animals, may have become a distinctive part of adult behavior because of reduced opportunities for hunting (Hall 1998).

SECTION II. NON-AVIAN REPTILE BEHAVIOR, EVOLUTION, AND PHYSIOLOGY

The behavior, evolutionary history, and physiology of squamate reptiles in general, and monitors specifically, are discussed here in relation to the occurrence and ability to play and interact with enrichment such as novel objects. The objectives of this current study are presented along with general hypotheses and predictions.

Non-avian Reptile Play

Since scientists have been reluctant to classify non-avian reptilian behavior as play behavior (Bekoff and Byers 1981), there has been little incentive to provide enrichment for these animals (Fagen 1981; Burghardt 1984). These objections have mainly been based on the assumption of non-avian reptiles' relatively low intelligence and their small brains; in other words, the idea that play is restricted to "higher" animals and that this behavior is evidence of advanced mental functioning. Not only their brain size, but also the lack of homeothermy and relatively low metabolic rates have also been reptilian traits associated with the inability to play. These traits in mammals (increased brain size in relation to body size, endothermy, and increased metabolic rates) were thought, in the surplus resource theory, to have served as the motivational sources to play behavior (Burghardt 1982, 1984). But perhaps non-avian reptiles do not play in the mammalian way, or we simply have not observed these animals in contexts conducive to play.

Nevertheless, there were a few early reports of non-avian reptilian play in the American Alligator (*Alligator mississippiensis*) (Lazell and Spitzer 1977) and the Komodo dragon (*Varanus komodoensis*) (Hill 1946) though these were anecdotal and undocumented by film or video. Recently play has been confirmed in the Komodo dragon, one of the few non-avian squamate reptiles for which documented records for play exist (Burghardt et al 2002). A few documented reports of play have also been reported in turtles (Burghardt 1998; Burghardt et al. 1996; Kramer and Burghardt 1998). These turtles' object and social play behavior fit all five play criteria listed in Section I (Kramer and Burghardt 1998).

Monitors

If play was to be found in non-avian reptiles, authors have predicted it would be seen in crocodilians due to their extensive parental care and varanid lizards due to their relatively high metabolic rate (Fagan 1981; Burghardt 1984; Burghardt 1988). Monitor lizards may be the best candidates for the study of mammalian-like play in squamate reptiles. This is not only because of their physiology, but also their foraging abilities (Cooper and Burghardt 1990; Kaufman et al. 1994; Kaufman et al. 1996; Phillips 1995) and their unique life-history traits (Ciofi 1999) as compared to other squamate reptiles. Monitor play is a good test for the surplus resource theory because they appear to have some of the physiological traits associated with play in animals (Burghardt 1984, 1988).

Evolution and Life History

Lizards are the most successful non-avian reptiles as measured by the sheer number of species and include 20 (on some counts 27) living families. This group of non-avian reptiles exceeds all others in anatomical, behavioral, and reproductive diversity as well as extent geographical diversity. Most lizards are terrestrial and are active by day. Many species constantly use their tongue to sample molecules and retrieve them into their mouth in order to collect chemical information on food, mates, territories and predators. Lizards with long, forked tongues, such as beaded lizards, whiptails, and monitors, have further developed this ability compared to other lizards, which mainly use the tongue for capturing prey rather than chemosensation. Most lizards are predators feeding on insects, small terrestrial invertebrates as well as, in larger lizards, mammals, birds and other reptiles. Only 2% of all lizards are primarily herbivores (Pianka and Vit 2003; Halliday and Adler 2002).

Some monitors are the largest of all living lizards and are related to mosasaurs – fossil marine lizards (which were much larger than present day monitors) and snakes. Lizards and snakes represent the reptilian order squamata. Squamates include a variety of non-avian reptiles, which are divided into two suborders, Sauria (Lacertilia/lizards) and Serpentes (Ophidia/snakes). Monitors are in the infraorder Diploglossa and the superfamily Platynota. The Platynota or Varanoidea include Helodermatidae (Beaded lizards), Lanthanotidae (Earless Monitor), and Varanidae (Monitors) and are the closest lizard relatives of snakes (Pianka and Vit 2003; Halliday and Adler 2002; Bellairs 1970).

Like snakes, most monitors swallow prey whole and usually headfirst. Most monitors share the common body shape with an elongate body, well-developed limbs, and strong claws on all digits. The monitor neck is usually long and the tail is muscular and slightly to highly laterally compressed. The are two radiations of monitors, classified by geographical distribution, Old World (African and Asian) and Australian. The Old World monitors are primary African or Asian species (Halliday and Adler 2002; Bellairs 1970).

Sensory Capabilities

Monitors have good hearing, sight, and sense of smell as compared to most other non-avian reptiles, although compared to mammals some of these abilities may be limited (Ciofi 1999; Steel 1996). Though incapable of vocalizing, monitors use hearing to aid in defense or foraging. Compared to mammals, non-avian reptile hearing is limited. Among non-avian reptiles, however, monitors have good hearing. The varanid cochlea is the most advanced among lizards, though it contains fewer receptor cells than mammals (Ciofi 1999).

Visually varanids seem better at picking up movement than stationary objects, but have poor vision in dim light (Ciofi 1999). Recently, the eye structure of the varanid, *Varanus griseus caspius*, was investigated (Roll 2002). Cells in the retina usually include both rods (low light vision) and cones (bright light and color vision). Although, most species have both of these cells, pure cone retinal structure is found

in many diurnal lizards. The varanid retina appears to contain no rods, but does contain different types of cone cells as well as colored oil droplets. Therefore, the varanid eye has the morphological basis for color vision (Roll 2002).

The varanid primary food detectors are the chemical senses of smell and vomerolfaction, as true of many other squamate reptiles. The highly developed Jacobson's organ (a pair of sensory sacs opening into the roof of the mouth in front of the internal nasal apertures) is characteristic of all monitors and the monitor's tongue is forked and extremely specialized for this mode of chemoreception. Unlike some other lizards, the monitor's tongue has an exclusively sensory function and is devoid of taste buds. The monitor's flicking tongue samples particles from ambient air currents and moves past the Jacobson's organ. These particles are then transported to the ducts of the Jacobson's organ by ciliary action. Using the Jacobson's organ as a major source of sensory input, the monitor can assess whether potential prey or enemies are nearby. A monitor samples the air currents and molecules in its vicinity, rather than sniffing them as a mammal does. Its tongue will sample a volume of air at least as great (if not greater) than the similar tongue of structurally advanced snakes (Steel 1996; Gove and Burghardt 1983).

Physical and Brain Size Variance

Monitor lizards all share a distinctive body form but vary greatly in size. This diverse genus includes 57 species (Halliday and Adler 2002). Varanid species vary in adult mass by nearly five orders of magnitude. No other terrestrial vertebrate genus exhibits this range in size variance (Pianka 1995). In a recent study, prevalence and complexity of play was significantly correlated with brain size with larger-brained orders having more playful species (in mammals) (Iwaniuk et al. 2001). It was also noted that those species with the largest brains in their taxa were more likely to play into adulthood. The results of this comparison across mammalian orders revealed a significant positive relation between play and brain size. Only large increases in brain size, as evident across orders, may have had a role in evolution. The authors concluded that there was a stepwise relationship between brain size and play. That is, a large difference in brain size affects play, but small differences do not (Iwaniuk et al. 2001). This trend in mammalian taxa could possibly be similar in reptilian taxa, again leading to the increased possibility that varanids play.

Physiology

Not only the varanids' senses, but also their general physiology lends to these animals being more "mammal-like" then other non-avian reptiles. As discussed below, varanids have an unusually efficient heart and lungs (Horn 1997), a larger more complex lung structure leading to more efficient gas exchange, a more complete ventricular septum in the heart (which facilitates less mixing of oxygenated and unoxygenated blood), as well as an increased metabolic rate and an increased core body temperature as

compared to other lizards (Steel 1996). All of these traits further support the possibility that these animals have the ability to play.

Respiratory System

The varanid saccular lungs are proportionately twice the size of those normally found in lizards. This allows a higher level of gas exchange and is similar to the complex ultra-efficient lungs of birds and mammals. The ability to sustain high levels of aerobic activity and recover rapidly is due largely to this complex lung structure, which allows the lungs to be readily dilated by non-respiratory functions in order to achieve efficient ventilation. Varanids are much more efficient in oxygen use compared to other lizards. Monitors remove more oxygen from the air as well as consume more oxygen during activity, largely due to the complex lung structure with greater surface area than many other species (Steel 1996).

Gular pumping during sustained activity further enhances the superior respiratory system of the monitors. It is thought that most lizards use a lateral undulatory gait, which prevents effective lung ventilation during moderate to high-speed locomotion. If this was true, as the lizard increases activity, just when it needs more oxygen, it is actually able to breathe less effectively. This restriction on activity level is termed an axial constraint. In a recent study, Owerkowicz (1999) compared green iguanas to monitor lizards during sustained activity. Though the green iguanas showed an axial constraint as expected, the monitors circumvented this constraint by using accessory gular pump to augment costal ventilation (Owerkowicz et al. 1999).

Circulatory System

The increased efficiency of the varanid respiratory system complements an advanced heart and circulatory system as compared to a normal, typically conservative, non-avian reptilian arrangement (Steel 1996). Although the varanid circulatory system is not comparable in efficiency to the mammalian heart, the degree of intra-ventricular mixing is limited and represents an enhanced level of efficiency compared to typical squamate reptiles. Varanids also have a higher oxygen transportation capability. This is not due to any increase in oxygen affinity of hemoglobin but to an avoidance of metabolic acidosis during activity. Varanids, compared to other squamate reptiles, also have a higher level of myoglobin, equal to that of mammals. Myoglobin facilitates rapid transfer of oxygen from the blood to the muscle fibers during activity. Due to the combination of these respiratory and circulatory advances in the use of oxygen, monitors can maintain comparatively high levels of sustained activity, by non-avian reptilian standards. In this respect, varanids are almost intermediate between typical non-avian reptiles and more energy-efficient mammals (Steel 1996).

Metabolic Rate

All of these factors (increased complexity in the lung structure, limited intraventricular mixing, avoidance of metabolic acidosis during activity, higher level of myoglobin, and utilization of gular pumping) combine to result in the high aerobic activity of varanid lizards (Frappell et al. 2002). The monitor's capacity for sustained activity transcends the capabilities of most other non-avian reptiles and approaches the warm-blooded mammalian level (Steel 1996). The respiratory and circulatory factors are further enhanced by the varanid's increased metabolic rate.

The high aerobic metabolic rate of many varanids is an exception among lizards. Squamate metabolic rates increase with increasing mass at a higher rate than expected. The rate is greater than that observed for the class-wide analysis of the metabolic rate of mammals (Andrews 1985). This is possibly due to the development on an efficient predatory specialization that can require both sustained and bursts of high energy and may be why there are no strict herbivores in this family. The relative increase in the standard metabolism of varanids may reflect their life history traits, particularly their widely foraging and primarily carnivorous diet (Thompson 1997).

Natural History

Ecologically, monitors are comparable to small to medium-sized species of predatory mammals. They occupy similar ecological niches in Australia and compete well with mammals of comparable size in Africa and Asia. Varanids successfully inhabit diverse ecological environments including deserts, steppes, relatively dry forests, tropical humid rainforests, rivers and riverbanks, and marine shores (Horn 1997).

One of the primary traits associated with play in mammals is postnatal care. The presence and degree of parental care seems mostly related to ecological conditions, such as unstable environments (e.g. temperature, humidity, or precipitation) and predation (by both other species or conspecifics). This type of environment could lead to the need for further protection of eggs or neonates (Burghardt 1984, 1988). Most squamate reptiles deposit their clutch on or in the ground with some preparation, cover, or protection. However, some species of monitors go through complex behavior when laying a clutch that offers an unique form of protection. *V. albigularis* and many other species (*V. giganticus, V. gouldii, V. rosenbergi, V. niloticus, V. salvator*, and *V. varius*) dig a deep tunnel into a termite mound and lay their clutch at the end of this tunnel, after which the termites seal the hole. Once the wall of the mound is hardened, no predator, other than another monitor, will be able to disturb the eggs. The termites control the incubation temperature and humidity, which means the embryos have suitable incubation conditions for proper development (Pianka and Vit 2003).

If these environmental factors are compared to the eggs in a bird's nest or to the offspring of a mammal, the eggs of a monitor have far better chances for survival in terms of protection and stability until hatching. After oviposition, a varanid female may also guard the area where a clutch was laid from competitive females or predators. This behavior was seen in a female Komodo defending its nest site

successfully against a larger competitive female and a far bigger male, which was in search of the eggs (Horn 1997). Some of these species, when the young are near term, will even dig the neonates out of the termite mound (Steel 1996).

All of these physiological, life history, and behavioral traits seem to allow monitors to be more "mammal-like" in their predatory strategy and communication as well as overall behavior (Auffenberg 1978; Fagen 1981). This leads to the prediction that these animals are capable of higher cognitive behaviors as well as curiosity and play.

Current Study and General Predictions

Captive Environment

The current study was conducted at the Dallas Zoo in off exhibit enclosures. There are advantages and disadvantages to conducting research in zoos. The advantages are the availability of rare or endangered species, familiarity with subjects, as well as repeatability and longevity of experiments. Smaller populations allow the researcher to conduct many more trials on only a few individuals, thus getting a better contextual picture of the overall responses (Saudargas and Drummer 1996). The data are more likely to be accurate, for an individual, if multiple trials can be conducted with the same object or stimulus (in laboratory experiments individuals are rarely tested multiple times, the preference is many different individuals tested few times). With the increased ability to repeat experimental conditions, habituation and longevity of an enrichment regimen can also be explored (Saudargas and Drummer 1996). The history of the individual animal and the natural and life history of the species is also usually well known by the researcher in a captive study. This is very important when formulating the experimental design as well as when interpreting the behaviors observed (Greenberg 1994). Finally, the zoo environment also seems to allow researchers to increase the overall time of a research project. While in most field and laboratory studies observations and experiments are conducted over only a few months, zoo research is usually conducted over years (Saudargas and Drummer 1996).

Along with these advantages there are also several disadvantages when conducting a zoo study. These include lower statistical power, inability or difficulty in generalizing across species, concerns of public opinion and presence, as well as less environmental control. Zoo research usually involves only one subject, or a small sample size, due to animal availability. The main disadvantage occurs when analyzing the data due to the fact that many statistical tests are most powerful with at least a sample size of twenty-five. The small number of individual animals also leads to difficulty when trying to hypothesize an expected behavioral pattern generally across an entire species. When conducting zoological studies, the public also has to be considered if the animals are on exhibit during trials. If the trials include animals on exhibit, the public opinion and the problem of educating the public as to what is taking place, as well as the

effect the public has on the animals' behavior, must be considered. Finally, there may not be much environmental control in an outdoor enclosure (Saudargas and Drummer 1996).

These disadvantages are taken into account in this current study. They were considered and noted when recording the behaviors as well as when analyzing the data. The advantages were also fully realized with multiple trials over a long period of time per individual as well as detailed accounts of each individual's history.

Species

Eight Black-throated monitors were observed in an enriched environment during this study. Most research has been on the White-throated savanna monitor (Kaufman et al 1994 and 1996; Phillips 1995; Secor and Phillips 1997) and as of yet there have been no morphological (besides color of the throat), physiological, molecular, or behavioral differences noted between these two monitors (White and Black-throated monitors) and both are considered the subspecies *Varanus albigularis albigularis* (Bennett 1998). So it is assumed that past research, as well as field and captive observations of White-throated monitors, applies to Black-throated monitor as well. The Black-throated monitor inhabits the grasslands of south and east Africa and experiences months of fasting during the dry season (Secor and Phillips 1997). This monitor, like most large monitor species, was incredibly difficult to study in the field due, in part, to harsh habitat and large home ranges (Phillips 1995). Though the natural behavior of monitors is hard to observe, studies on captive animals should be useful. The lack of captive research is most likely due to the only recent success in captive rearing and breeding. Now that these goals have been met to a considerable degree, further investigation into the specifics of monitor behavior must be implemented to enhance the quality of their captive lives by providing appropriate environments and experiences (Burghardt 1996).

Summary of Experimental Protocol

This systematic study analyzed the videotaped behavior of eight individually housed juvenile Black-throated monitors, *V. a. albigularis*, in response to an enriched environment involving presentation of three types of objects, including social introductions. This study was conducted at the Dallas Zoo in Texas by zoo staff, primarily Ruston Hardtegan, in 2001. The tapes were collected and then I analyzed them and created ethograms to further understand these object introductions.

This study compared the responses of these eight monitors to two objects containing prey and one containing a clutchmate. One goal was to compare differences in the amount and intensity of the monitors' responses, as well as the overall level of activity levels during the sessions, to these objects. The monitors' abilities to discriminate, learn, explore, and play in the presence of the objects were also compared and analyzed.

General Predictions

I predicted that, when objects were introduced to the monitors, play and exploratory behavior as well as predatory and social behavior would be exhibited. One of the main concepts involved in formulating the predictions was surplus resource theory, as mentioned in the discussion of play in Section I. The concept that captive animals have all other needs met, combined with the physical evidence to support the use of excess energy during play, supported my overall hypothesis. I expected to document exploration, play, habituation, and learning in the monitors' responses to the different objects.

SECTION III. METHODS

The Dallas Zoo and the University of Tennessee Reptile Ethology Lab developed a joint study on enrichment with Black-throated monitors that included a comparison of noninvasive MRI brain images of enriched individuals with a control group that received no enrichment. All animals came from the same clutch. This neurological study also provided an opportunity to observe and analyze the behavior of these monitors during object introductions provided for enrichment. Eight juvenile monitors and their reactions to and interaction with two objects and novel conspecifics in a systematic experimental protocol were videotaped and analyzed.

Subjects

This study included 16 monitors: eight enriched and eight control animals from the same clutch. However, only the enriched subjects were given objects and thus available for analysis. The monitors hatched in November of 2000 and were about three months old when introduced object enrichment began in February of 2001. The monitors were measured and weighed each month after hatching. The eight enriched individuals observed during the object introductions are identified by the following numbers: 611 (female), 612, 613 (male), 614 (male), 615 (male), 618, 621, 622 (female) (Appendix Table A-1 and 2). Because the animals were under one year of age during testing, three individuals could not be sexed due to the fact that hemipene calcification does not usually show up on radiographs before one year.

Housing and Maintenance

The group of eight individuals investigated in this current study were housed in enriched enclosures that included eight centimeters of Cyprus mulch substrate, a horizontal shelf (at approx. 15 cm height, 61 cm long) that ran along the length of the back wall, a hide box (approx. 20 x 15 x 8 cm) that was placed under the shelf to allow more floor space, and painted enclosure walls so the animals could not see one another but could see the outside activity (Figure 1). The cages were approximately 122 x 61 x 46 cm and were acrylic. Each was divided into two enclosures measuring approximately 61 x 61 x 46 cm by a plywood wall. Each cage had a 85 watt spot lamp giving a basking area of about 105-115 degrees F as well as a double bulb 61cm fluorescent fixture with Sylvania 350BL bulbs (20 watts). The monitors were given a basking area that ranged between 30 and 40 degrees Celsius. There was also a plastic water bowl measuring approximately 15 centimeters in diameter and six centimeters deep.

In the beginning of the trials, because the monitors were so young, they were fed twice a week, one feeding of crickets and one feeding of 2-3 fuzzies (young furry mice). Trial days were spaced between feedings. The monitors were not on display during the trials. Usually the monitors would go one weekend without food (Friday through Sunday), tested on Monday, and fed on Tuesday. On Thursday, the trials would be run again and the monitors would be fed after the trials, given that all went as planned during the

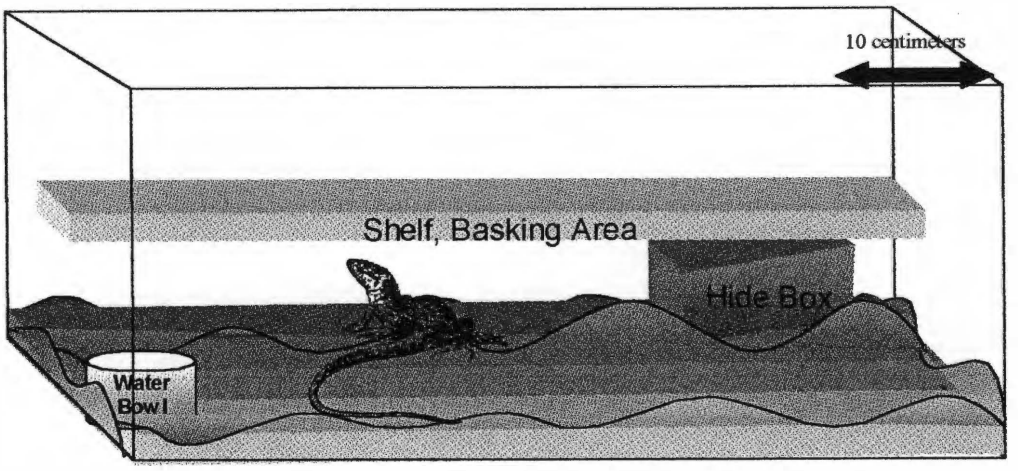


Figure 1. Diagram of Black-throated Monitor Enriched Enclosure.

week. After the monitors were six to seven months old (three months into trials), they were fed only mice and only once a week (usually Tuesdays).

The eight control individuals were kept in enclosures with cage paper substrate, no additional furnishings (no shelf), walls were painted all the way around (i.e., no visibility to outside except through the enclosure top) and hide boxes were placed in the corner but were moved around quite a bit by the animals. The control group was only given dead prey in feedings. These animals were compared to the enriched group in an additional set of trials comparing the social interactions of two groups of four lizards, all from either the enriched or from the control groups, when each group was placed in a large opaque container and observed for two hours. The control group was not used in the present comparison. The future analysis of the additional social trials will hopefully further the exploration and understanding of the monitors' responses to social introductions and continue to support the theories derived in this study concerning the need for enrichment in reptiles, specifically the resulting increase in activity in captive monitor lizards due to object introductions.

Procedure

Experimental Design

Each twenty to twenty-five minute session included a fifteen-minute introduction as well as 2-3 minutes of pre and post introduction observations documented for each trial. The pre and post intervals were recorded on videotape to document baseline, introduction, and post test behaviors. Table 1 summarizes the trials, the order each object was introduced, and the number of days between each type (FB=Food Ball, FT=Food tube, S=Social) of trial in the sequence. All eight enriched monitors were given the same objects in the same order throughout the experiment. All sessions were taped from outside of the

Table 1. Summary of Black-throated Monitor Trials Including Date and Days Between Trials.

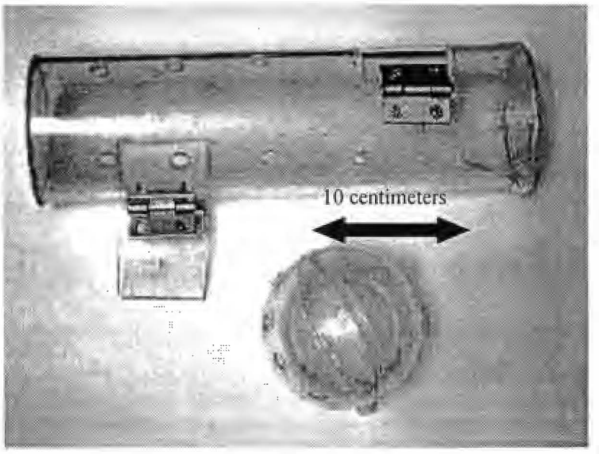
Sequence Number of Object Presented		Date of Trial	# of Days Between Trials	# Days By Object Between Trials
Food Ball	1	February 7, 2001	-	FB 2: 20
Social	1	February 26, 2001	19	FB 3: 7
Food Ball	2	March 5, 2001	6	FB 4: 9
Social	2	March 7, 2001	2	FB 5: 7
Food Ball	3	March 12, 2001	5	FB 6: 5
Social	3	March 14, 2001	2	FB 7: 15
Food Ball	4	March 21, 2001	7	FB 8: 13
Food Ball	5	March 28, 2001	7	FB 9: 10
Food Ball	6	April 2, 2001	5	FB 10: 6
Social	4	April 5, 2001	3	FT 2: 8
Food Ball	7	April 17, 2001	12	FT 3: 7
Social	5	April 18, 2001	1	S 2: 7
Food Ball	8	April 30, 2001	12	S 3: 7
Social	6	May 3, 2001	3	S 4: 22
Food Ball	9	May 9, 2001	6	S 5: 13
Food Ball	10	May 15, 2001	6	S 6: 15
Social	7	May 17, 2001	2	S 7: 14
Food Tube	1	May 22, 2001	5	S 8: 21
Food Tube	2	May 30, 2001	8	
Food Tube	3	June 5, 2001	7	
Social	8	June 7, 2001	2	

enclosure and were recorded in full. Only one trial per individual was completed per day. Trial days were spaced between feedings and one object and one social trial was completed (if possible) per week. The specifics of each trial are detailed in the Appendix Tables A-1 and A-2.

In a zoo situation it is not always possible to carry out a standard large group design with high subject numbers and matched control groups (Saudargas and Drummer 1996). One way to help alleviate this problem is to implement a repeated measures design. The preferred method is the ABAB design, or the baseline (A), experimental condition (B), reinstatement of baseline conditions (A), and reinstatement of experimental condition (A) design. Due to time and environmental constraints, however, most zoo research cannot carry out the full ABAB design. This current study is based on the minimized ABA design. The trials all consisted of some data on the individual's behavior before (A), during (B), and after (A) an object was introduced in an effort to measure normal baseline, interactive, as well as post-trial behaviors.

Objects Introduced

Each of the eight enriched monitors underwent a series of 20 trials in the same order. These trials included three types of introductions. Two of these were object introductions associated with prey (Figure 2), the food ball and food tube (prey could be retrieved) trials.



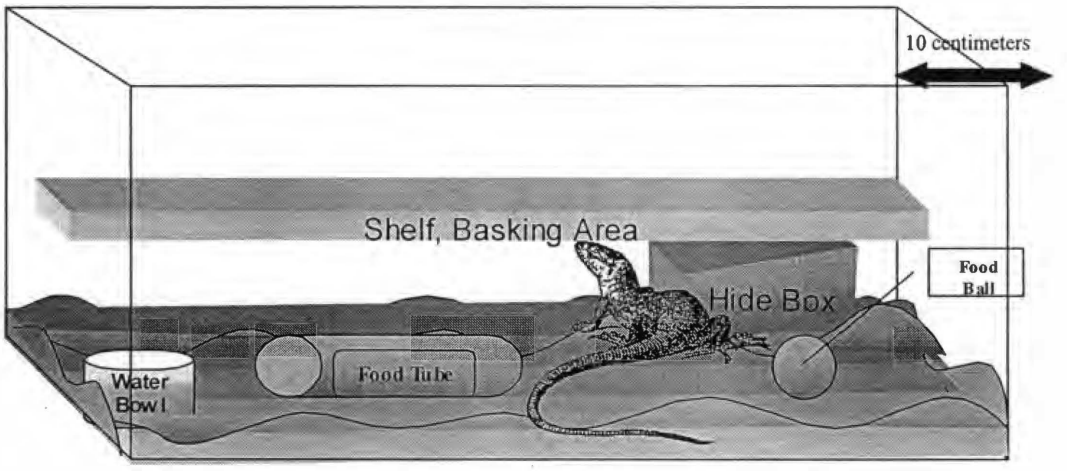


Figure 2. Images of Prey Objects. Top: Picture of Prey Objects. Bottom: Diagram of Enriched Enclosure to Show the Size Ratio of Prey Objects (Normally not Both at Same Time) to Black-throated Monitors During First Trial.

Food Ball

One object was the food ball, a clear plastic ball 7.6 cm in diameter with 11 holes (0.5cm in diameter) drilled on each side. This object was split in half, two to three live fuzzies were placed inside, and then the two sides were screwed together and secured before the object was introduced. The monitor could see and smell, but not attain the prey in these trials. There were ten food ball trials conducted for each of the eight individuals.

Food Tube

The second food enrichment trial involved a food tube which was a clear plastic tube 20.3 x 6.4cm with four rows of holes (0.5cm in diameter) and two hinged doors. Every other row had five holes drilled in a parallel line along the tube. Two rows had three holes followed by a hinged door (3.5 x 3.5cm) on opposite ends of the tube. Two to three live fuzzies were placed inside the tube. In these trials, the monitors could possibly retrieve the prey from the object. There were three food tube trials conducted for each of the eight individuals.

Social

The third trial was a social enrichment (Figure 3) involving one lizard from the enriched group being placed in a small clear plastic pet container with a screened lid 22.9x12.7x17.8cm and then introduced in the home cage of another enriched individual. This process was repeated (seven trials for each) until each monitor had been introduced to each of the other enriched monitors.

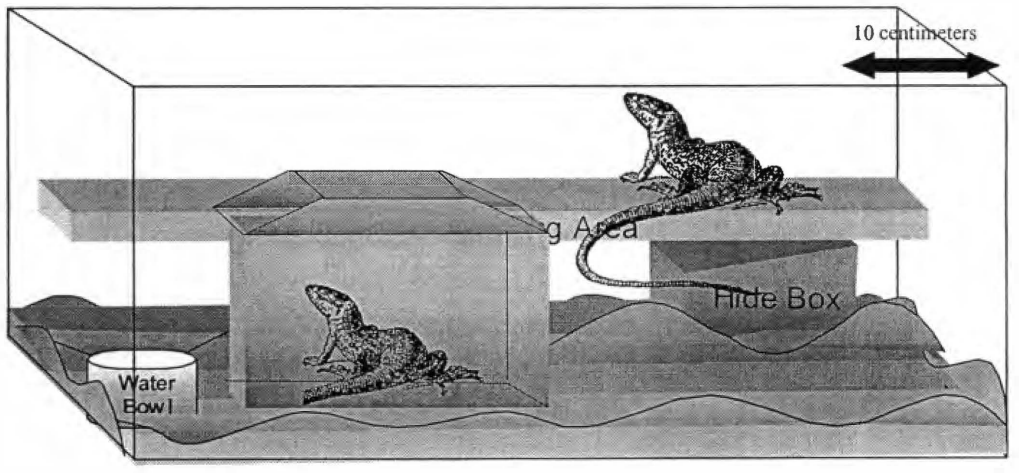


Figure 3. Diagram of Enriched Enclosure to Show the Size Ratio of Social Stimulus to Black-throated Monitors During First Trial.

Data Analysis

Ethogram

During the video analysis many behaviors were identified and an ethogram was constructed. These behaviors were then grouped or ranked by actual occurrence. The Observer® program (Noldus) was used to quantify the behavior in the trials through a repeated viewing of the tapes. The behavior patterns in the ethogram are divided into either states or events. State behaviors are those with a measurable duration and event behaviors are those that are nearly instantaneous and that are best quantified using occurrence analysis (Lehner 1996). Of the behaviors observed, twenty-five were found useful in comparing the different trials. Descriptions of the state and event behaviors, the abbreviation for the behavior, and a brief description of the movement or position involved in each behavior, are provided in Tables 2 and 3.

The modifiers involved with both state and event behaviors indicate to what or to whom the behavior is directed toward. The modifiers used are **ob** (indicating the behavior was directed toward the introduced item) and **ot** (indicating the behavior involved was directed toward other objects in the enclosure [e.g. glass, substrate, or tree stump]). The state behaviors that are separated by modifiers are approach (**AP**) and head insertion (**HI**).

Some of these behaviors were described by Auffenberg (1981) in field observations including rest, shake, swallow, walk, climb, mouth grab, and tongue flick. During my observations, resting was recorded when the monitor was immobile as described in Table 2. The monitors were usually resting, or basking, on the highest point in their enclosures (second shelf in enclosure, Fig 1). The resting positions observed were described by Auffenberg (1981) in a field study of Komodo dragons as "posterior adpression" (resting in a sort of seated position) and "ventral adpression" (lying down). Both of these resting positions were considered basking behavior in these wild populations.

Approaching the object (**APob**) occurred mostly in the beginning of the introduction. This behavior was distinguished from interaction (**INob**), since there was no physical contact with the object. Approaching the object usually began with a directed motion, or "bee-line", towards the object followed by a circling behavior. General approaching behavior (**APot**) was also recorded when it seemed the monitor was moving toward the other objects such as the glass window of the enclosure. Another state behavior involving the object was moving the object (**MO**). This behavior was enacted when the monitor mouth grabbed the object, held on, and dragged or carried the introduced object.

The overall interaction with the object (**INob**) included the time spent involved in physical contact and being attentive to the object for more than five seconds, while the state behaviors move object (**MO**) and head insert (**HIob**) were recorded only when the monitor was moving the object or inserting its head into the object. The event behaviors (quick behaviors only recorded for occurrence) involving the object during interaction, discussed below, were also recorded. Finally, there were also three general state

Table 2. State Behaviors Observed During Videotape Analysis in the Black-throated Monitor Studies.

Behavior Pattern	Description
1. Resting (**RS**)	1. There was no movement besides maintenance (tongue flicks, breathing, or head movement) activity. Resting was categorized by two forms: **RS**s a seated position (front legs still straight) and **RS**l a lying down (all four legs spread, belly touching ground) position.
2. Walk (**WA**)	2. Moving around enclosure with no apparent orientation toward a particular object. Usually monitors were walking around the perimeter of the enclosure in and out of the brush.
3. Approach (**AP**)	3. Movement directed toward a specific item in the enclosure. This behavior was most often enacted when the monitor was approaching the introduced object (**AP**ob) or when the monitor was approaching the glass of the enclosure (**AP**ot).
4. Moving (**MO**)	4. Apparent purposeful physical movement, of the introduced object, by the monitor. For example, both monitor species would pick up or push the object usually with the head/mouth and move it around the enclosure.
5. Head Insertion (**HI**)	5. Head inserted at least two thirds into the object for at least five seconds. This occurred with the introduced object (**HI**ob) and rarely into the substrate (**HI**ot).
6. Interact (**IN**ob)	6. Interacting with object. Monitor spent more than a few seconds in physical contact and /or chasing and being attentive to object introduced.
7. Digging (**DI**)	7. Digging in substrate. This motion occurred usually with alternating front claws scraping and with rostrum angled and sometimes burying into substrate.
8. Defecation (**DF**)	8. Hind Legs lowered, body lowered, then a side-to-side movement while defecating.
9. Head Hidden (**HH**)	9. Anterior portion of body (head and front legs) was covered usually under the second level of the enclosure or under substrate (Black-throated). At these points it was impossible to record tongue flicks, movement, or the actual position of the monitor. This behavior was also inacted when the session began and the monitor could not be found, until it emerged during the trial.
10. Escape Horizontal (**EH**)	10. Pacing along edge of enclosure snout nudging and fore scraping the glass wall
11. Escape Vertically (**EV**)	11. Up on hind legs, fore scraping wall in vertical position
12. Walk Up (**WU**)	12. Walking on second level of enclosure
13. Seesaw (**SE**)	13. Legs space apart and body swaying forward and back or side-to-side. Sometimes a series of head bobs would accompany this motion.

Table 3. Event Behaviors Observed During Videotape Analysis in the Black-throated Monitor Studies.

Behavior Pattern	Description
1. Tongue Flick (**TF**)	1. A single extension and retraction of the tongue from the mouth. The fast tongue flick was recorded when just the simple motion of bringing the tongue in and out in a fairly quick manner occurred.
2. Lick (**LI**)	2. Slow tongue flick. The slow tongue flick was recorded when the tongue was out of the mouth and then went along the side of the snout, which usually was a much slower motion then the rest of the flicks.
3. Snout Nudge (**SN**)	3. Pressing the snout into an object in a short swift movement often resulting in moving the object.
4. Fore Scrape (**FS**)	4. Moving the forearm and claws onto the object and then pulling back and out along the substrate.
5. Mouth Grab (**MG**)	5. A bite at object with mouth open followed by the object being held in the mouth for more than 0.1 second. It typically was followed by a shake or head insertion.
6. Shake (**SH**)	6. With the object held in the mouth, monitor would shake the head back and forth. Shaking was categorized in two forms. Shake fast (**SHf**) occurred in 0.1 seconds or less. Shake slow (**SHs**) occurred in greater than 0.1 seconds.
7. Yawn (**YA**)	7. Mouth slowly, but briefly, opens wide. Usually from resting position.
8. Tail Swipe (**TS**)	8. The tail is rapidly whipped.
9. Bite (**BI**)	9. Quick snap towards object with mouth open, though object is not held with the mouth as in mouth grab.
10. Head wipe (**HW**)	10. With the head bent down towards the object, the head is then swiped sideways back and forth on the object.
11. Capture Prey (**CP**)	11. Recorded at time when monitor first captured prey, followed by ingestion.
12. Drink (**DR**)	12. Tongue flick directed into water bowl.

behaviors to delineate the rest of the time spent by the monitor including digging (**DI**), defecation (**DF**), and head hidden (**HH**).

There were some complex locomotion behaviors, escape horizontally (**EH**) and escape vertically (**EV**). These behaviors involved very rapid movements along the perimeter of the enclosure walls, either horizontally or vertically. These behaviors occurred most often after the object was removed, or, in later trials, after the monitor seemed to lose interest in the object. The walk up (**WU**) behavior involved walking up onto the second level of the enclosure and included instances when the Black-throated monitors were making "walking" movements while in a stationary vertical position against the enclosure wall. The seesaw (**SE**) behavior was also a fairly complex behavior seen, for the most part, only in the social stimulus trials. This pattern seemed to be a display behavior brought on by the presence of the introduced individual in the subject's home cage. All of the state behaviors were recorded as durations. The number of occurences was also compared among the state behaviors that occurred most often: **RE, WA, AP, MO, HI, and INob**.

Within these thirteen state behaviors, twelve event behaviors were recorded. Tongue flick (**TF**) frequencies were an overall measure of the monitors' activity during the trials. Tongue flicks (**TF**) were recorded through video observations. Tongue flick rates are a good measure of overall activity in squamate reptiles (Burghardt and Pruiit 1975), and therefore reflect how active the monitors were before the object was introduced (pre-introduction), during the trial, and after the object was removed (post-removal). A similar event behavior, lick (**LI**) was also measured. The lick was basically a slow tongue flick as described in Table 3. These slower tongue flicks (licks) usually occurred when the monitor was resting and were most likely to occur right after interaction with the object.

Four of the twelve event behaviors were directed at the object introduced, snout nudge (**SN**), fore scrape (**FS**), mouth grab (**MG**), and shake (**SH**). Snout nudge (**SN**) and fore scrape (**FS**) occurred mainly with the non-prey like trials. Both mouth grab (**MG**) and shake (**SH**) were also observed and described by Auffenberg (1981) from field studies. The shake (**SH**) was defined occurring when the prey was slung side-to-side and sometimes pounded against the ground (Auffenberg 1981). It appears to be derived from a predatory movement for stunning, killing, or further tearing the prey. The mouth grab (**MG**) events were described as a "bite" followed by gripping with the teeth (Auffenberg 1981).

The yawn (**YA**) did not occur often during the trials, but when observed occurred in the pre-introduction periods. The tail swipe (**TS**) occurred when the tail was curled tight against the body then swiftly swiped. In the Black-throated monitor trials this behavior occurred most at the introduction or removal of the object (most frequently the social stimulus, the largest apparatus introduced) and was mostly directed toward the keeper's hand. However, in the first few social introductions, this behavior occurred and was directed towards the individual introduced.

The bite (**BI**) behavior was a very quick bite or snap towards the object. Head wipe (**HW**) was most prevalent in the social trials and involved the monitor climbing/walking up onto the top of the

introduced individual's small enclosure and wiping its head over and over on the lid. The capture and onset of the ingestion of the prey (**CP**) was also recorded in the Black-throated monitor trials. Finally the drink behavior (**DR**) was recorded. Overall, most of these behaviors have been observed and documented in field studies of wild monitors. From these descriptions, the behaviors observed in captivity, at least by definition, mimic those in the wild.

Analysis

General/Grouped Behaviors

Data for all behaviors observed in the trials were analysed in three ways, including duration, occurrence, and changes over trials. Tongue flick rates were also analyzed within the trials. These measures were compared across objects and individuals. Another part of the analyses pooled the state behaviors into general categories in order to get a better overall picture of the monitors' behavior.

The specific behaviors (See Tables 2 and 3 for definitions) were pooled according to type of movement as well as what the behavior involved or was directed toward (using the modifiers discussed earlier). The Rest (**RE**) category included all resting behaviors (**RS**). Locomotion (**LO**) included all state behaviors representing movement, not directed at the object: walk (**WA**), escape (**EV** and **EH**),walk up (**WU**), Head Insert other (**HIot**), Digging (**DI**), Defecation (**DF**) and approach other (**AP***ot*). Interact (**IN**) included approach object (**AP**ob), moving (**MO**), interact object (**IN**ob), and head insert object (**HI**ob). Finally the Other category (**OT**) included head hidden (**HH**) durations, though these durations were relatively short and were omitted from this analysis. These groupings are summarized in Table 4.

In addition to the grouped behavior categories, a more specific analysis involved only those behaviors directed toward the object in order to further investigate the response of the monitors' to each type of object. This was accomplished by dividing the interact with object (**IN**) category into the frequencies of the specific state and event behaviors involved. The only comparisons that took within-session time data into account were those involving the tongue-flick counts.

Statistics

The behaviors were first analyzed overall by graphing the patterns observed in the trials. Through these visual representations, a general picture is given of what responses were elicited in each type of introduction. In general, parametric tests are usually preferred to non-parametric because they are more powerful and robust (Searle 1999). The increased power of parametric statistics is mainly due to the use of raw scores in the calculations. Parametric tests look at the size of values, not just the order. The data in this study were very complex and included both independent, categorical, as well as dependent continuous variables. In essence the data were, overall, too complex to run nonparametric analyses without sacrificing much of the information contained in the raw data (Conover 1999).

Table 4. Summary of Pooled Behavior Patterns used in the Analyses of the Black-throated Monitor trials.

Pooled Behavior Pattern	**Description**	**Specific Behaviors Included *Detailed Definitions in Table 2.**
1. Rest (**RE**)	1. There was no movement besides maintenance (tongue flicks, breathing, or head movement) activity.	Includes all Resting behaviors (**RS**): **RSs, RSl**
2. Locomotion (**LO**)	2. General movement, not involving the object.	Includes all movement behaviors: Walk (**WA**), Approach other (**APot**), Head Insert other (**HIot**), Digging (**DI**), Defecation (**DF**), Escape Horizontal (**EH**), Escape Vertical (**EV**), and Walk up (**WU**)
3. Interaction (**IN**)	3. Interaction with the object.	Includes all behaviors directed toward the object: Approach object (**APob**), Moving object (**MO**), Head Insert into object (**HIob**), Interact object (**INob**), and Seesaw (**SE**).

Another reason to use parametric tests for these data is that, in general, parametric tests can be used on a smaller sample than non-parametric tests. Finally, it is argued by many statisticians that parametric tests do not produce many errors and are, therefore, more robust even if there are small violations of the underlying conditions (Franklin et al. 1997).

There were ten food ball, three food tube, and seven social trials conducted for each of the Black-throated monitors. With twenty trials per individual, this study was robust and suited for parametric statistics. These data were analyzed using MANOVA. MANOVA was used due to its ability to handle this complex data set as well as its overall robustness to violations of normality. This test was also utilized in order to see the main and interaction effects of this type of mixed data set. To test the releationship between the independent and dependent variables, Wilk's lambda was performed. This is the most common traditional test where there are more than two groups formed by the independent variables. The second step in the MANOVA was to determine just which group means differ significantly from others. For this procedure, the least significant difference test (LSD), also called Fisher's LSD or the protested t-test was conducted. The analysis compares all possible pairs of means after the F-test rejects the null hypothesis that the groups do not differ. A Discriminant Analysis was also performed on the data to show that the objects introduced could be predicted by the behaviors elicited during the trials. There were also ordered repeated measure MANOVAs conducted on the tongue flick data to compare the within trial tongue flick counts over two minute intervals. With only eight individuals and unbalanced treatments in

the study, all such statistical tests must be viewed with caution. All analyses were conducted using SPSS 11.5 (SPSS Inc., 1989-2002).

All statistical tests were conducted using a significance of $p \leq 0.05$. Though there were multiple tests conducted, only one null hypothesis was being tested at a time and all tests were one-tailed. Thus, though multiple comparisons were made, statistical significance remained at $p \leq 0.05$.

As mentioned earlier, this study had a fairly large data set. Through observation, some preliminary trends have been seen in terms of the patterns of behavior during the different object introductions. These patterns could be analyzed using both lag sequential, to identify strong patterns, and Markov correlation analysis to investigate the statistical significance and interdependence of individual behavior patterns (Lehner 1996). These analyses will be conducted at a later date in order to explore the behaviors elicited in the Black-throated monitor trials.

Comparisons

The main comparisons made were among the different objects, across trials of the same objects, and among the individuals. Both mean occurrence and percent duration (to adjust for differences in trial times) were compared. First the pooled behaviors (Locomotion, Interaction with Object, Interaction with Human, Resting, and Tongue Flick) and then the specific behaviors, as listed in the general methods section, were compared. The occurrence of tongue flicks was also compared in the pre, during, and post intervals of the observed trials. It was found that there were significantly more tongue flicks during the object introductions than in the pre or post interval ($p=0.000$, LSD) and there were significantly more tongue flicks in the post interval as compared to the pre interval ($p=0.006$, LSD). This was consistent across virtually all baseline, introduction, and post test periods.

The tongue flick data and behaviors were also used to compare the different objects as well as in comparing the first, second, and third trial for each object. MANOVA was again used in these analysis to compare the trials. A multiple measures MANOVA was conducted to compare the tongue flick data over two minute intervals throughout the entire sessions. This was in order to further illustrate any habituation that may have occurred. Another factor investigated was the number of times an outside noise (talking, radio, water) was noticed by the individual in the trial. There was no significant difference found in the occurrence of these noises among the individuals or types of objects presented.

SECTION IV. RESULTS AND DISCUSSION

The difference in the monitors' responses to the objects as well as among individual monitors were compared both among and within the treatments. The general null hypothesis for these data was that the Black-throated monitors would exhibit no difference in their responses to the different stimuli. More specific alternative hypotheses and basic statistical results are given (based on rejecting the null hypothesis above) in order to estimate the significance of the trends across time both within and among the different trials as observed in the graphs.

Response to Different Objects

Overall Response

Food Ball

The first stimulus the monitors were exposed to was the food ball, the smallest and therefore most movable object introduced. The food ball was presented to each of the monitors over ten trials and was therefore the most frequent treatment. The prey within this object could be seen and smelled but not attained. The primary interaction with the food ball involved fore scraping (**FS**) and moving the object (**MO**) rapidly around the enclosure with many instances of circling or approaching the object (**AP**) (Figure 4 and 5[1]). Though the first few trials involved some biting (**BI**), most of the trials involved bouts of moving the object by snout nudging (**SN**) and pushing the food ball both around the perimeter and across the center of the cage during the introduction. In other words, during the food ball trials, the monitors would interact for a lengthy period and during this interaction, they would **AP** more often than have any direct physical contact with the object (**INob**) (Figure 4 and 5).

Food Tube

The second object, which also contained prey, was the food tube. All three of these trials were completed after the ten food ball trials. The food tube was larger and more awkward to move than the food ball, though it was moved (**MO**) in some of the trials. When it was moved, the food tube was mouth grabbed (**MG**) at the edge of one of the hinged doors and shook side to side with both fast and slow movements (**SH**). The most frequent mode of interaction with this object involved head insertion (**HI**) which was the behavior elicited in order to capture (**CP**) the prey within the tube. Before and during **HI** the monitors would also fore scrape (**FS**) first at the hinged doors, then inside the tube, as they searched for the prey. There were also bouts of **BI** before and after the prey were ingested. The **BI** were

[1] All figures refer only to those behaviors (AP, HI) directed at the object, unless otherwise stated.

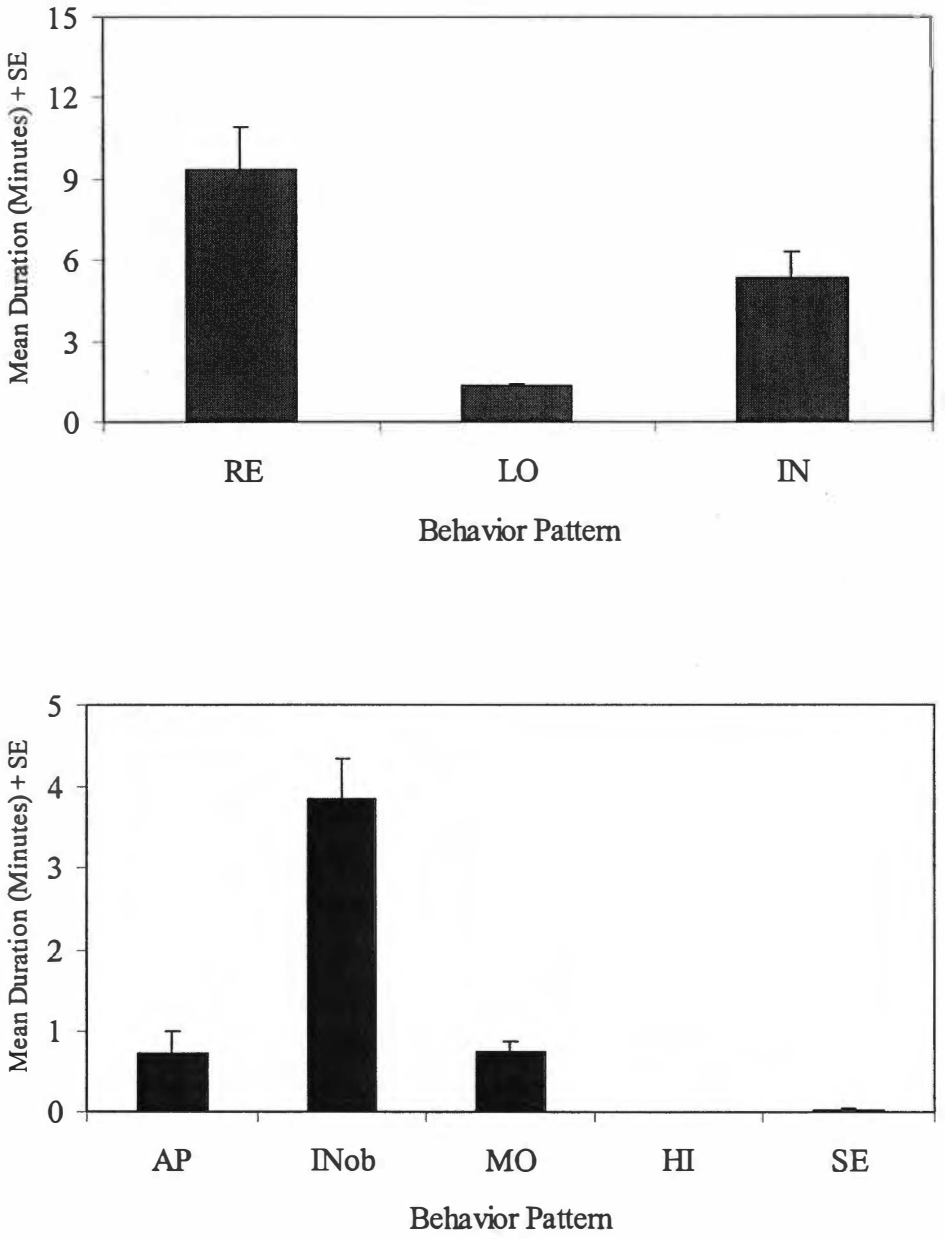


Figure 4. Mean Duration (Minutes) of Pooled State (Top) and Interaction (**IN**) State (Bottom) Behavior Patterns of the 8 Black-throated Monitors in all 10 15-Min Introductions of the Food Ball. **RE**=resting, **LO**=locomotion, **INob**=Interact with object, **AP**=approach object, **MO**=moving object, **HI**=head insert, **SE**=seesaw.[2]

[2] SE represents Standard Error in all Figures.

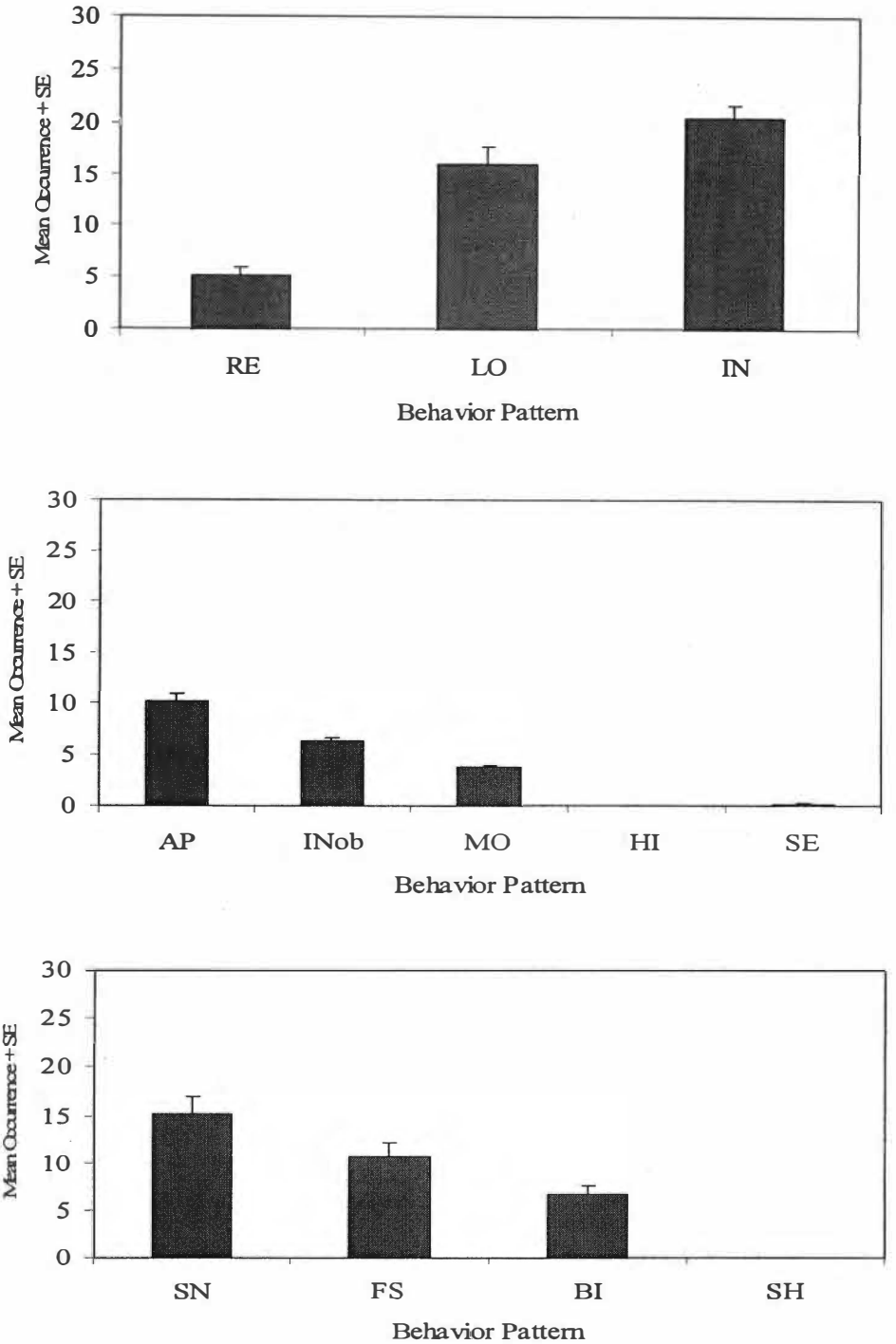


Figure 5. Mean Occurrence of Pooled State (Top), Interaction (**IN**) State (Middle), and Interaction (**IN**) Event (Bottom) Behavior Patterns of the 8 Black-throated Monitors in all 10 15-Min Introductions of the Food Ball. **RE**=resting, **LO**=locomotion, **INob**=interact with object, **AP**=approach object, **MO**=moving object, **HI**=head insert, **SE**=seesaw **SN**=snout nudge, **FS**=fore scrape, **BI**=bite, and **SH**=shake. **SN, FS, BI, and SH all occurred during INob or MO state behaviors.

usually directed at the hinge of the doors and were fairly rapid and repeated. Overall the monitors were very active in the food tube trials (Figure 6 and 7).

Social

The social stimulus was a container housing a conspecific and took up a large portion of the enclosure (Figure 3). The monitors would usually pause before moving around (**LO**) and approaching the introduced conspecific (**AP**). Initially however, the lizards typically performed the seesaw behavior (**SE**), a forward and back or side to side swaying motion, sometimes accompanied by head bobs, only seen in the social trials. The monitor would then approach the object (**AP**) and fore scrape (**FS**) the sides while standing vertically against the container and finally climb up on top of the cage. Once on top, bouts of head wiping (**HW**) would occur, while the monitor moved around to each of the corners of the lid. There were also some bouts of biting (**BI**) that were usually directed at the handle on the lid of the object (Figure 8 and 9).

Comparison of Behaviors Elicited

Hypothesis One: *Different behavior patterns would be elicited in response to the different objects.*

It was predicted that the monitors would respond differently to each of the three objects introduced because the objects were very different. The food ball contained prey but the monitors could only see and smell, but not attain or ingest, the prey. The food tube contained prey that the monitors could see, smell, attain, and ingest by opening the hinged doors and head inserting. The social stimulus did not contain prey, was very large, and contained a conspecific, which the monitors could see and smell, but could not have physical contact.

The overall behaviors performed were compared for each of the three objects, along with overall tongue flicks rates, which can also serve as a measure of general activity (Burghardt and Pruitt 1975). Statistical analysis was carried out to confirm the trends observed. It was found that there were significant differences in both duration (of state behaviors) ($p=0.000$ Wilk's Lambda, Table 5) and occurrence (of state and event behaviors) ($p=0.000$ Wilk's Lambda, Table 6) of the twelve behaviors listed above (**RE, LO, IN, AP, INob, MO, HI, SE, SN, FS, BI, SH, TF**) when comparing the three objects introduced.

Duration

There were no significant differences in the duration of the resting (**RE**) and locomotion (**LO**) pooled behaviors alone. Overall, the food ball kept the monitors very active. Although there were no significant differences found in the pooled **LO** behavior, there were significant differences in the specific

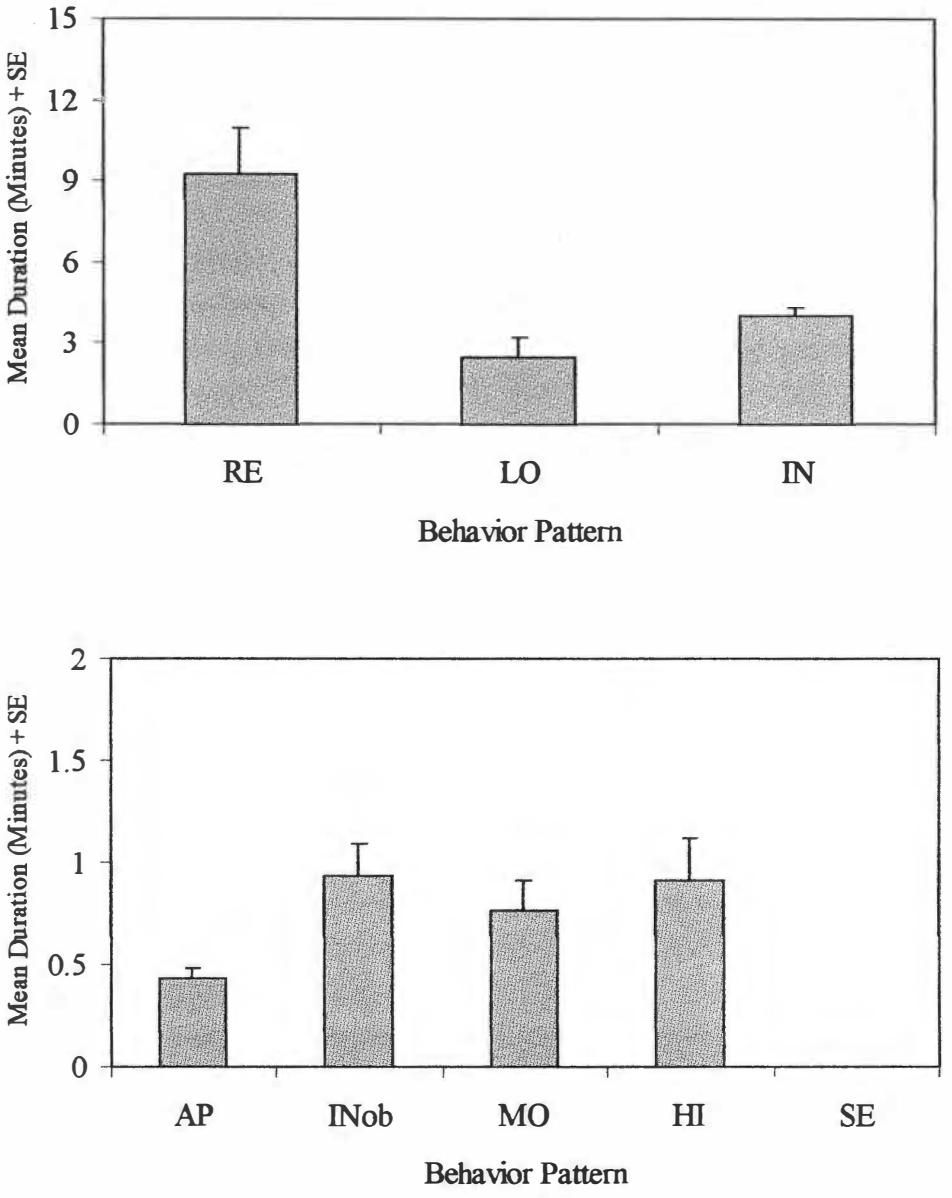


Figure 6. Mean Duration (Minutes) of Pooled State (Top) and Interaction (IN) State (Bottom) Behavior Patterns of the 8 Black-throated Monitors in all 3 15-Min Introductions of the Food Tube. Abbreviations for Behaviors as in Figure 4.

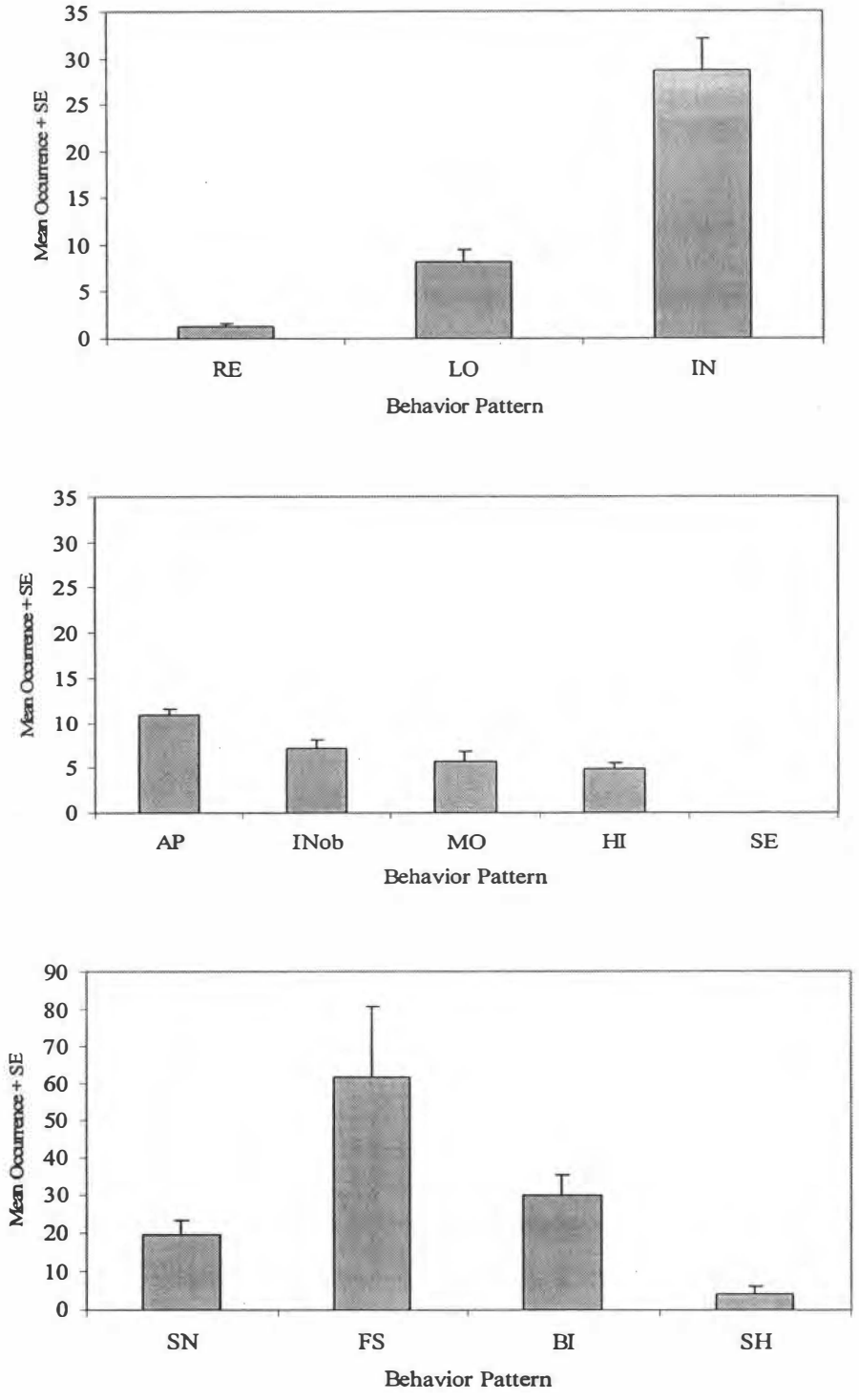


Figure 7. Mean Occurrence of Pooled State (Top), Interaction (IN) State (Middle), and Interaction (IN) Event (Bottom) Behavior Patterns of the 8 Black-throated Monitors in all 3 15-Min Introductions of the Food Tube. Abbreviations for Behaviors as in Figure 5.

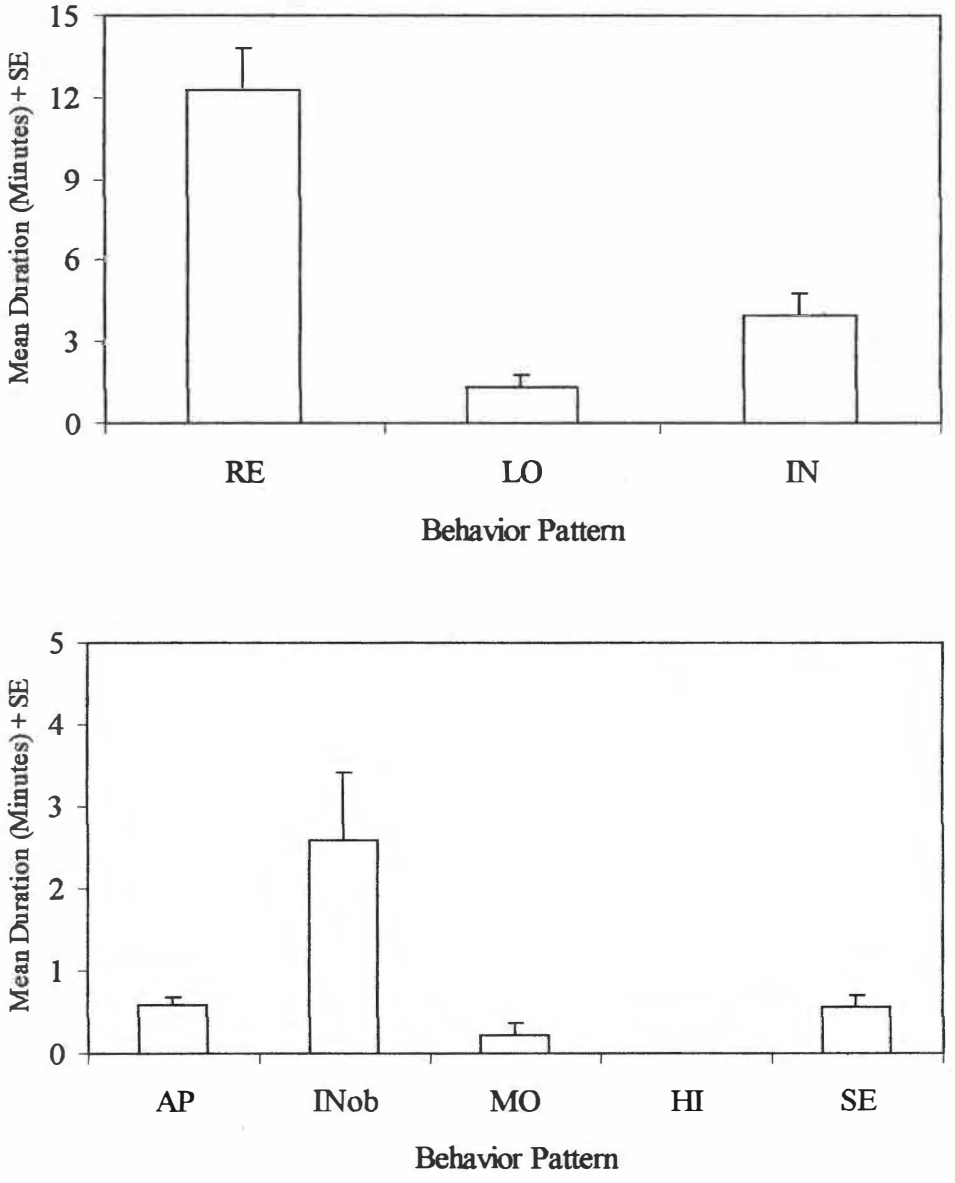


Figure 8. Mean Duration (Minutes) of Pooled State (Top) and Interaction (IN) State (Bottom) Behavior Patterns of the 8 Black-throated Monitors in all 7 15-Min Introductions of the Social Stimulus. Abbreviations for Behaviors as in Figure 4.

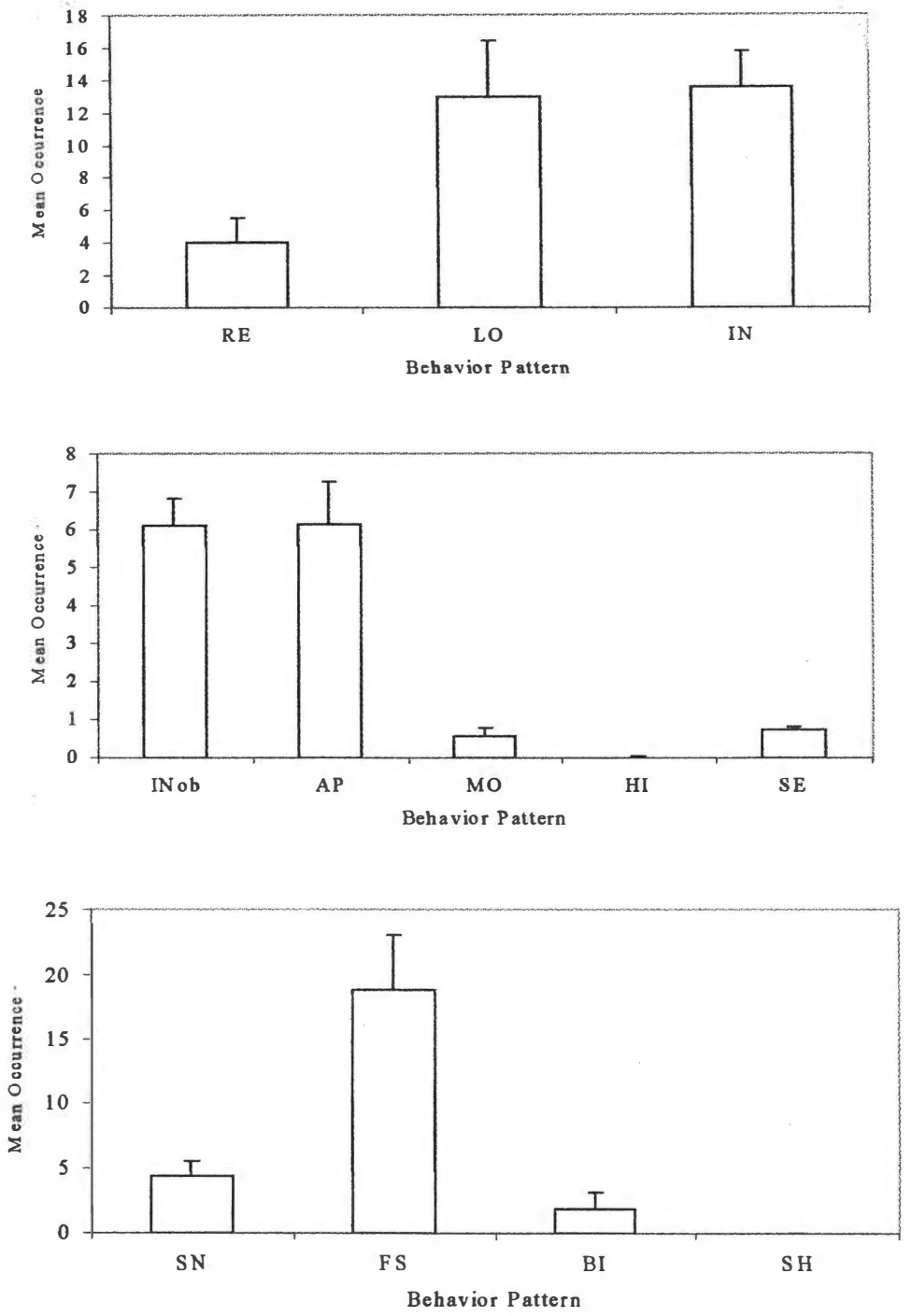


Figure 9. Mean Occurrence of Pooled State (Top), Interaction (**IN**) State (Middle), and Interaction (**IN**) Event (Bottom) Behavior Patterns of the 8 Black-throated Monitors in all 7 15-Min Introductions of the Social Stimulus. Abbreviations for Behaviors as in Figure 5.

Table 5. Multivariate Tests of State Behavior Patterns Observed in Black-throated Monitor Trials. (**RE, LO, IN, AP, INob, MO, HI, and SE**).[3]

Effect	Wilk's Lambda	F	Hypothesis df	Error df	Sig.
Intercept*	0.334	46.146	6.00	139.00	**0.000**
Object*	0.458	24.663	6.00	310.00	**0.000**

Table 6. Multivariate Tests of Mean Occurrence of State and Event Behavior Patterns Observed in Black-throated Monitor Trials. (**RE, LO, IN, INob, AP, MO, HI, SE, SN, FS, BI,SH,** and overall **TF** count)

Effect	Wilk's Lambda	F	Hypothesis df	Error df	Sig.
Intercept*	0.017	1438.996	6.00	152.00	**0.000**
Object*	0.442	12.772	11.00	302.00	**0.000**

locomotion behaviors (p=0.000 Wilk's Lambda, Table 7 and 8, Figure 10). The food ball led to significantly longer durations of escape vertically (**EV**) than all of the other trials (p<0.048 LSD, Appendix Table A-5 and A-6, Figure 10). The food ball, as expected, seemed to keep the monitor's interest for longer periods as compared to the food tube and social trials. Though durations of the resting (**RE**) and locomotion (**LO**) pooled behaviors were not significantly different, there were significant differences in the duration of the pooled interaction (**IN**) and the specific interaction state (approach (**AP**), interact (**INob**), move (**MO**), head insert (**HI**), seesaw (**SE**)) behaviors (p<0.000 Wilk's lambda, Table 5 and Table 9, Figure 10) when comparing the different objects.

The food ball elicited longer periods of actual physical contact and interactions (**IN**) than the other trials (Figure 10). When those interaction behaviors were further analyzed, the food ball trials again showed this trend in both the large amount of time spent approaching, or circling the object (**AP**) (Figure 10). The food tube trials were more similar to the food ball trials than to the social trials in the analysis of the time spent and the specific behaviors involved (Appendix, Tables A3-A6).

Occurrence

The food tube led to a significant difference in the occurrence of all of the grouped behaviors (p<0.006 LSD, Table 6, Appendix Table A-3 through A-6). The food tube elicited fewer occurrences of resting (**RE**) and locomotion (**LO**) than the food ball and social trials. The overall occurrence of locomotion (**LO**), i.e., general activity not directed at the object, was further analyzed by specific behaviors. There were significant differences found in this analysis among the different types of trials and in the behaviors involved in **LO** (p=0.000 Wilk's Lambda, Table 10). There was also significant differences in occurrence of walk (**WA**), walk up (**WU**), escape horizontally (**EH**), and escape vertically (**EV**) motions (p<0.047 LSD, Table 11) among the different objects introduced. The food ball elicited

[3] All behaviors abbreviated in statistical tables are as in Figures 4 and 5 and in all table * indicates significant difference between objects for the behaviors.

Table 7. Multivariate Tests of Mean Duration of Locomotion State Behaviors. (WA, WU, EH, EV)

Effect	Wilk's Lambda	F	Hypothesis df	Error df	Sig.
Intercept*	0.334	46.146	6.0	139.000	**0.000**
Object *	0.645	5.685	12.0	278.000	**0.000**

Table 8. Univariate Tests (Between-Subjects) of Durations of State Locomotion Behaviors. (WA)Walk, (WU)WalkUp, (EH)Escape Horizontally, (EV)Escape Vertically

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig
Corrected Model	WA	3578.771	9	397.641	8.397	**0.000**
	WU	17.065	9	1.896	1.384	0.200
	EH	2568.870	9	285.430	5.694	**0.000**
	EV	215.6000	9	23.956	3.654	**0.000**
Intercept	WA	11604.179	1	11604.179	245.060	**0.000**
	WU	18.828	1	18.828	13.747	**0.000**
	EH	1714.040	1	1714.040	34.196	**0.000**
	EV	87.940	1	87.940	13.413	**0.000**
Object Intro*	WA*	2579.966	2	1289.983	27.242	**0.000**
	WU*	9.348	2	4.674	3.413	**0.036**
	EH*	783.120	2	391.560	7.812	**0.001**
	EV*	116.163	2	58.081	8.859	**0.000**
Error	WA	6818.750	144	47.352		
	WU	197.231	144	1.370		
	EH	7217.942	144	50.125		
	EV	944.134	144	6.556		

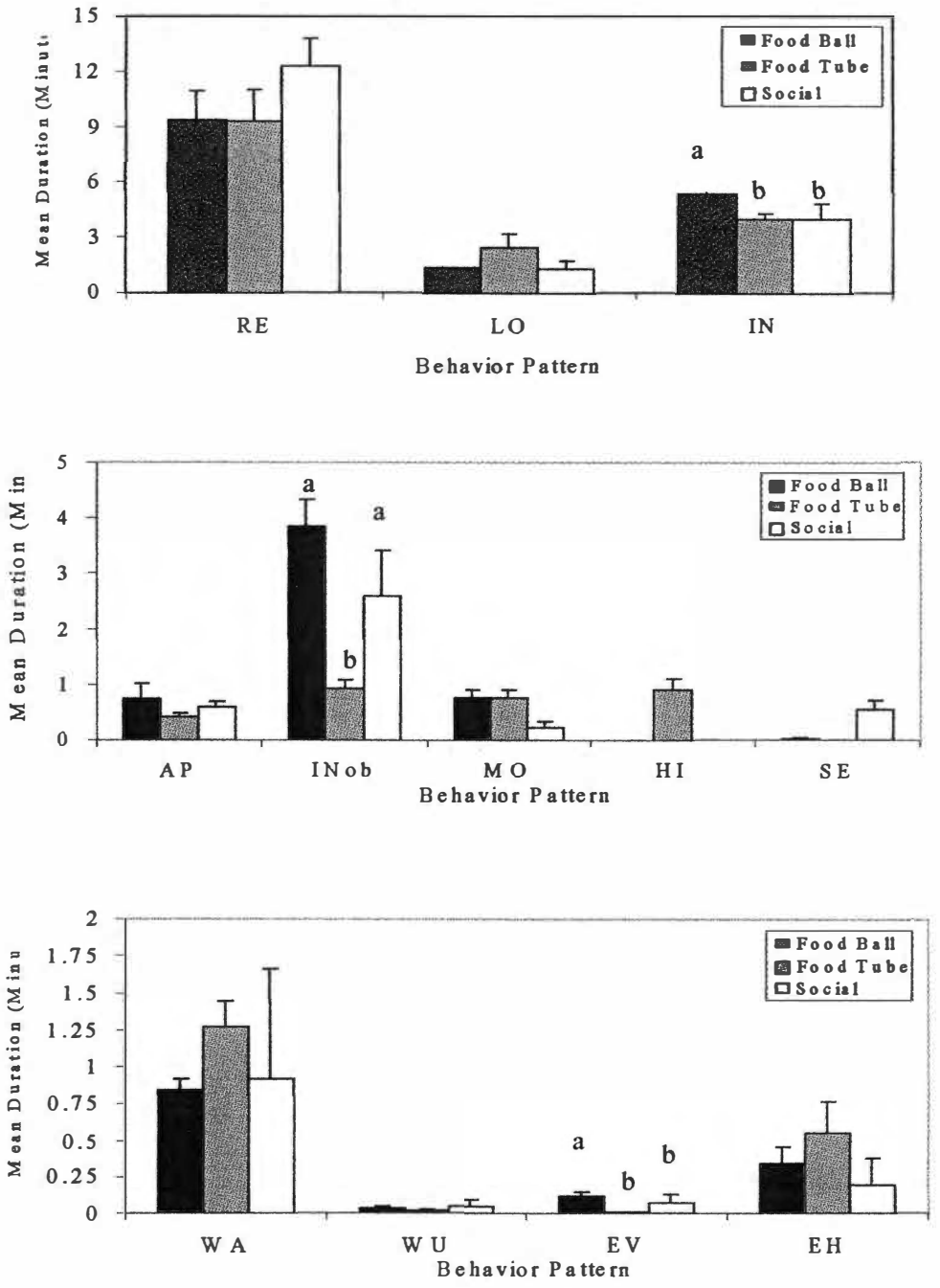


Figure 10. Mean Duration (Minutes) of the Pooled State (Top), Interaction (**IN**) State (Middle), and Locomotion (**LO**) State (Bottom) Behavior Patterns of the 8 Black-throated Monitors in all 15-Min Introductions of the Food Ball (N=10), Food Tube (N=3), and Social (N=7) Stimuli. Abbreviations for Behaviors as in Figure 4. (**WA**) Walk, (**WU**) Walk up, (**EV**) Escape Vertically, (**EH**) Escape Horizontally. Significant differences ($p<0.05$) indicated by letters.

Table 9. Univariate Tests (Between-Subjects) of Durations of State Behaviors Involving the Object Introduced. (HI)Head Insert, (IN)Interarct, (MO)Move object

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	HI*	2114.050	9	234.894	18.211	**0.000**
	IN*	23418.957	9	2602.106	12.232	**0.000**
	MO*	1335.215	9	148.357	3.397	**0.001**
Intercept	HI*	1290.237	1	1290.237	100.032	**0.000**
	IN*	82899.435	1	82899.435	389.693	**0.000**
	MO*	3394.551	1	3394.551	77.721	**0.000**
Object*	HI*	1893.606	2	946.803	73.405	**0.000**
	IN*	19265.248	2	9632.624	45.281	**0.000**
	MO*	1110.514	2	555.257	12.713	**0.000**
Error	HI	1934.739	150	12.898		
	IN	31909.511	150	212.730		
	MO	6551.428	150	43.676		

Table 10. Multivariate Tests of Event Locomotion Behaviors.

Effect	Wilk's Lambda	F	Hypothesis df	Error df	Sig.
Intercept*	0.290	34.535	10.0	141.000	0.000
Object Intro*	0.511	5.615	20.0	282.000	0.000

Table 11. Univariate Tests (Between-Subjects) of Event Locomotion Behaviors. Abbrev. as in Table 8.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	WA*	4448.590	9	494.288	8.579	**0.000**
	WU*	101.390	9	11.266	2.872	**0.004**
	EH*	578.029	9	64.225	3.961	**0.000**
	EV*	291.038	9	32.338	3.885	**0.000**
	TS*	19.755	9	2.195	2.756	**0.005**
Intercept	WA*	15257.219	1	15257.219	264.797	**0.000**
	WU*	69.807	1	69.807	17.796	**0.000**
	EH*	469.756	1	469.756	28.971	**0.000**
	EV*	87.813	1	87.813	10.548	**0.001**
	TS*	19.403	1	19.403	24.357	**0.000**
Object Intro*	WA*	3377.715	2	1688.857	29.311	**0.000**
	WU*	42.215	2	21.107	5.381	**0.006**
	EH*	306.285	2	153.143	9.445	**0.000**
	EV*	126.544	2	63.272	7.601	**0.001**
	TS*	5.462	2	2.731	3.428	**0.035**
Error	WA	8642.785	150	57.619		
	WU	588.385	150	3.923		
	EH	2432.165	150	16.214		
	EV	1248.706	150	8.325		
	TS	119.488	150	0.797		

significantly greater occurrences of escaping horizontally as compared to all of the other trials ($p=0.000$ LSD, Appendix Table A-5 and A-6). The food ball trials also led to significantly more occurrences of both dig (**DI**) and locomotion (**LO**) (Figure 11) than in the other trials ($p<0.03$ LSD, Appendix Table A-6).

There was also a significant difference between the pooled interaction behavior (**IN**) ($p=0.000$ Wilk's Lambda, Table 4) and the specific state and event interaction behaviors ($p<0.032$ LSD, Table 12). When the pooled interaction behaviors were further analyzed, the food ball trials again showed this trend in the number of times spent approaching, or circling the object (**AP**) (Figure 11). The food ball, as expected, seemed to keep the monitor's interest for longer periods as compared to the food tube and social trials. In the food tube trials interaction (**INob**) occurred significantly more often than in any of the other trials ($p<0.01$ LSD, Appendix Table A-4). However, in durations of the grouped behaviors, food tube trials led to shorter durations of interaction with the object, **INob** (Figure 10) and overall the food ball held the monitors' attention for longer periods although the food tube had more bouts of interaction.

Hypothesis Two: *The food ball would elicit more exploratory and play-like behaviors and keep the monitor's attention for longer periods of time as compared to the food tube.*

The event interaction behaviors were also analyzed and were found to be significant ($p=0.000$ Wilk's Lambda, Table 6). The food tube elicited significantly more fore scrape and bites as compared to the food ball and social stimulus ($p=0.000$ LSD, Appendix A-4, Figure 11).

As shown above, the food ball and food tube objects elicited different responses. Did, as was expected, the food ball elicit more exploratory and play-like behaviors and keep the monitor's attention for a longer period of time than the food tube, due to the fact that prey could be attained in the food tube? In the food ball trials the prey could not be attained and thus the monitors should continue to be attracted to, and interact with, this object. Also, since the predatory response, or consumatory reaction, could not be completed in the food ball trials, it was also expected that the monitors' behavior would change to more exploratory and play-like responses over time. In the majority of the food ball trials, all of the individuals began circling (**AP**) and snout nudging (**SN**) the object (Figure 11), while biting (**BI**) was only evident in the first few trials. The changes over food ball trials will be further discussed in relation to habituation and learning below. In all of these behaviors, food ball trials were much more like the social trials than the food tube trials (Figure 11, Appendix Table A-4).

Hypothesis Three: *The food tube would elicit more predatory-like behaviors than the food ball.*

As stated above in hypothesis one, the food ball and food tube were expected to elicit different behaviors. Just as the food ball was expected to elicit more exploratory and possibly play behavior because the prey could not be attained; the food tube was expected to elicit more predatory behaviors because the prey could be attained and ingested.

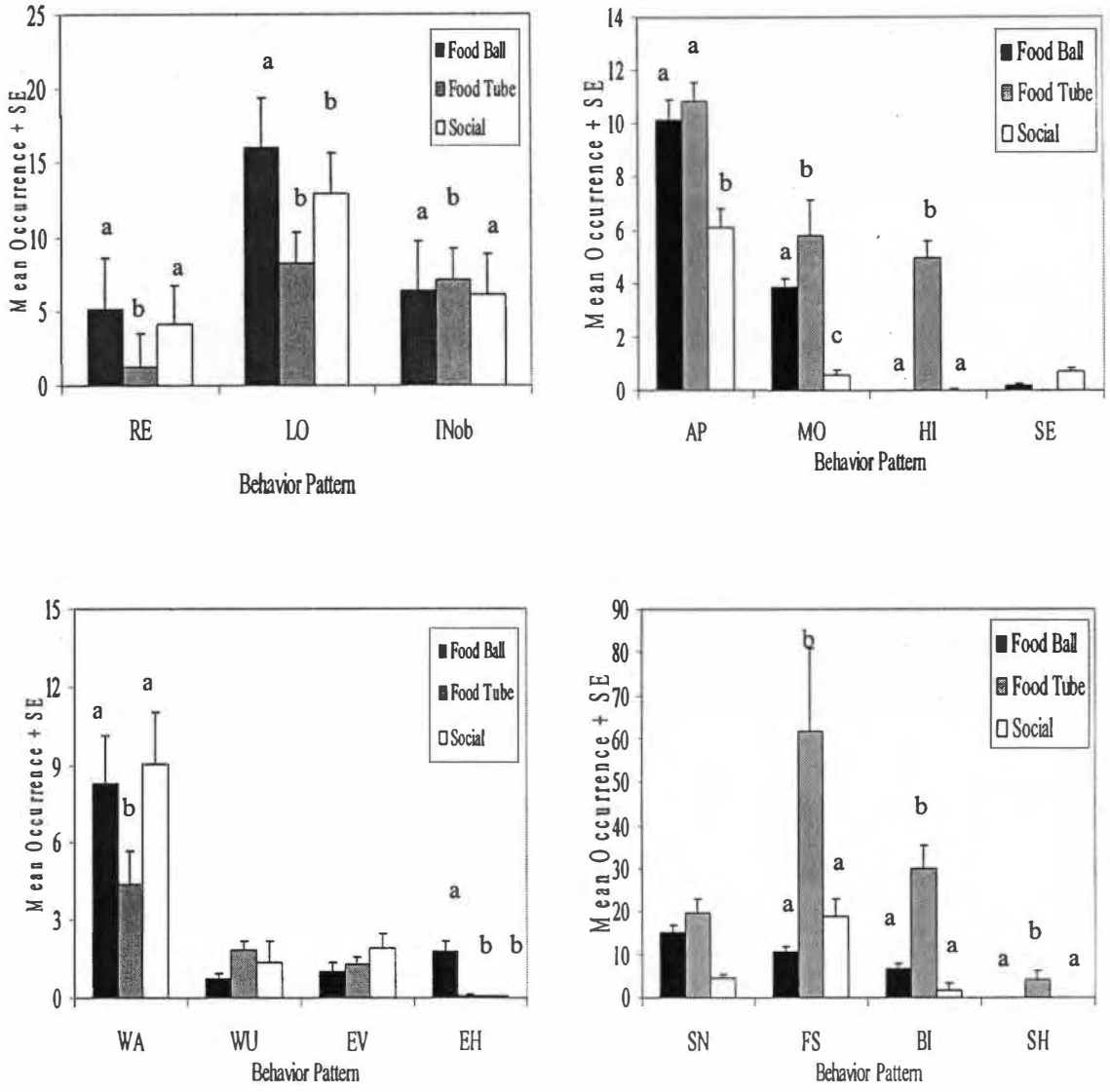


Figure 11. Mean Occurrence of the Pooled State (Top Left), Interaction (IN) State (Top Right), Locomotion (LO) State (Bottom Left), and Interaction (IN) Event (Bottom Right) Behavior Patterns of the 8 Black-throated Monitors in all 15-Min Introductions of the Food Ball (N=10), Food Tube (N=3), and Social (N=7) Stimuli. Abbreviations for Behavors as in Figure 5 and 10. Significant differences ($p<0.05$) indicated by letters.

Table 12. Univariate Tests (Between-Subjects) of Event Behaviors Involving the Object.

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig
Corrected Model	FS*	71788.622	9	7976.514	6.926	**0.000**
	BI*	12776.636	9	1419.626	13.367	**0.000**
	MG*	698.001	9	77.556	3.072	**0.002**
	SHs*	14.150	9	1.572	3.249	**0.001**
	SHf*	142.517	9	15.835	1.533	0.141
	HW*	81987.790	9	9109.754	18.881	**0.000**
	SN*	7433.909	9	825.990	3.845	**0.000**
	HI*	580.760	9	64.529	27.125	**0.000**
	AP*	1001.088	9	111.232	4.599	**0.000**
	IN*	2879.359	9	319.929	10.725	**0.000**
	MO*	698.151	9	77.572	8.223	**0.000**
Intercept	FS*	127428.251	1	127428.251	110.649	**0.000**
	BI*	19437.494	1	19437.494	183.017	**0.000**
	MG*	1195.939	1	1195.939	47.365	**0.000**
	SHs*	8.072	1	8.072	16.680	**0.000**
	SHf*	53.701	1	53.701	5.197	**0.024**
	HW*	36978.864	1	36978.864	76.641	**0.000**
	SN*	21473.400	1	21473.400	99.966	**0.000**
	HI*	391.413	1	391.413	164.533	**0.000**
	AP*	9656.738	1	9656.738	399.227	**0.000**
	IN*	13600.755	1	13600.755	455.938	**0.000**
	MO*	1611.263	1	1611.263	170.800	**0.000**
Object Intro*	FS*	57352.328	2	28676.164	24.900	**0.000**
	BI*	10879.792	2	5439.896	51.220	**0.000**
	MG*	651.107	2	325.553	12.893	**0.000**
	SHs*	11.256	2	5.628	11.629	**0.000**
	SHf*	72.742	2	36.371	3.520	**0.032**
	HW*	74110.315	2	37055.157	76.799	**0.000**
	SN*	5915.934	2	2957.967	13.770	**0.000**
	HI*	569.660	2	284.830	119.730	**0.000**
	AP*	653.313	2	326.657	13.505	**0.000**
	IN*	2581.359	2	1290.679	43.267	**0.000**
	MO*	595.607	2	297.803	31.568	**0.000**
Error	FS*	172747.322	150	1151.649		
	BI*	15930.858	150	106.206		
	MG*	3787.443	150	25.250		
	SHs*	72.594	150	0.484		
	SHf*	1549.858	150	10.332		
	HW*	72374.185	150	482.495		
	SN*	32221.066	150	214.807		
	HI*	356.840	150	2.379		
	AP*	3628.287	150	24.189		
	IN*	4474.541	150	29.830		
	MO*	1415.043	150	9.434		

In the interaction behaviors there were significant differences in the amount of time spent (Figure 10) head inserting (**HI**), interacting (**INob**), and moving the object (**MO**) ($p<0.000$ LSD, Tables 5 and 9) between the different stimuli. Specifically the monitors spent significantly more time **INob** in the food tube trials as compared to the food ball trials ($p=0.000$ LSD, Appendix Table A-3). The monitors spent more time approaching the object (**AP**) in the food ball trials, while in the food tube trials more time was spent **MO** and **HI** (Figure 10). The food tube had significantly longer durations of **MO** as compared to both the food ball and social Trials ($p<0.028$ LSD, Appendix Table A-3).

Finally, there were also differences in the occurrences of the interaction behaviors. The food tube elicited significantly more occurrences of head insert (**HI**), moving the object (**MO**) (Figure 11), fore scrape (**FS**), bite (**BI**), and shake (**SH**) (Figure 11) than all of the other trials ($p<0.016$ LSD, Appendix Table A-4). The monitors clearly reacted differently to the food ball and food tube.

Hypothesis Four: *Towards conspecifics, the monitors would be perform more socially interactive responses than to the prey objects.*

The social stimulus was very different from the other two trials. Each lizard was tested with the container with each of the other enriched individuals in a series of trials. Recall that the introduced individual was placed in a small plastic container (large enough for them to rear and turn around) with a mesh lid. The entire container was then placed in the subject's home enclosure. Also, because of the nonmovable nature of this object as well as its large size (which did not allow much space for movement within the enclosure) it was also expected that the monitors would be less active as compared to the food ball and food tube trials.

Even though it was a very different stimulus, the conspecific elicited similar amounts of time spent and occurrences of resting (**RE**), locomotion (**LO**), and interaction (**INob**) as compared to the food ball trials. The social stimuli elicited significantly fewer occurrences of approach object (**AP**), move object (**MO**), bite (**BI**), and snout nudge (**SN**) (Figure 11) than the other objects ($p<0.000$, LSD Appendix Table A-4).

The social stimuli elicited significantly more **TS**, **HW**, and **SE** than the two prey objects. These behaviors occurred rarely if at all in the other two types of trials. Observations showed that during the instant when the container was introduced, the subject would occasionally tail swipe (**TS**) or react aggressively from a defensive posture. This was probably due to the large size of the container and its threatening appearance as it was introduced abruptly down into the enclosure. The social stimulus also elicited more occurrences of tailswipe (**TS**) than the food ball ($p=0.01$, LSD Appendix Table A-6). Bouts of the Head wipe (**HW**) behavior occurred most often in these trials ($p=0.000$, LSD Appendix Table A-4). This behavior took place when the lizard had climbed on top of the conspecific's cage. Finally seesaw

(SE) was observed most often in the social trials for fairly long periods of time (Figures 10 and 11). This behavior seemed to be directed at the conspecific and occurred mostly in the first few social trials.

Predictability

The hypothesis that the different stimuli would elicit different behaviors was supported. To further support this finding, a discriminate analysis was conducted on the different behaviors, both duration and occurrence, elicited by the different stimuli introduced (Table 13 and 14). This analysis showed that, in general, the object introduced could be predicted by analyzing the behaviors elicited during the trials. The food ball trials were predicted correctly 100 percent of the time. This could be due to the increased number of trials with this treatment as compared to the food tube and social. If the other stimuli had been introduced at least ten times, they may have also had 100 percent predictability. The food tube was classified correctly about 80 percent of the time and was only misclassified with the food ball. This could have been due to the similarities of these two objects, in that they both involved visual and olfactory prey stimuli. Finally the social trials were predicted correctly 70 percent of the time. If these social trials were misclassified, they were also classified with the food ball trials. The misclassification could have been due to the fact that in both social and food ball trials there were no opportunities for consumption of prey.

Habituation and Learning

Hypothesis Five: *The Black-throated monitors would show greater habituation to the food ball, then to the food tube, and finally to the social stimulus over time.*

There were differences in the monitors' responses to the different objects, as described above. To further investigate this difference, habituation was compared among the objects both across trials during the introduction and within the trials. It was thought that the monitors would habituate first to the food ball, because the prey was unattainable and because the consummatory response was not possible. As there were also many more food ball trials, habituation might be more easily documented. The food tube was expected to show the second fastest habituation, because it was thought that the monitors would, over time, extract and ingest the prey faster with each trial. Finally, I was expecting little to no habituation in the social trials, due to each social stimulus presenting a new individual.

Habituation has been measured in various ways through different studies. Recently habituation has been measured by pairing consecutive trials and performing multivariate statistics to compare the different sets of trials (Bowers 1992). Here I will compare the first, second, and third trials for each of the objects (average of the eight individuals' responses) and the behaviors elicited.

Table 13. Summary of Canonical Discriminant Functions for Durations of Interaction State Behaviors (AP, INob, MO, HI).

A. Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.185	69.7	69.7	0.736
2	0.515	30.3	100.00	0.583

B. Wilk's Lambda

Function	Wilk's Lambda	Chi-square	df	Sig.
1	0.302	186.108	8	0.000
2	0.660	64.561	3	0.000

C. Standardized Canonical Discriminant Function Coefficients, Structure Matrix, and Functions at Group Centroids

	Canonical Function		Structure Matrix		Functions at Group Centroids		
	1	2	1	2	Object	1	2
AP	0.824	0.406	0.817	0.415	1.00	-0.741	0.517
IN	- 0.166	0.299	0.526	-0.634	2.00	2.434	0.538
MO	0.578	-0.779	0.160	0.509	3.00	0.015	-0.968
HI	0.114	0.546	0.032	0.199			

D. Classification Results

	Predicted Group Membership						
	Food Ball		Food Tube		Social		
Object Introduced	(N)	%	(N)	%	(N)	%	Total (N)
Food Ball	80	100.0	0	0	0	0	80
Food Tube	5	20.8	19	79.2	0	0	24
Social	17	30.4	0	0	39	69 .6	56

Table 14. Summary of Canonical Discriminant Functions for Occurrence of Interaction State and Event Behaviors (**AP, INob, MO, HI, FS, BI, SHs, SHf, HW**).

A. Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	2.682	65.4	65.4	0.853
2	1.417	34.6	100.0	0.766

B. Wilk's Lambda

Function	Wilk's Lambda	Chi-square	df	Sig.
1	0.112	334.450	18	0.000
2	0.414	135.006	8	0.000

C. Standardized Canonical Discriminant Function Coefficients, Structure Matrix, and Functions at Group Centroids

	Canonical Function		Structure Matrix		Functions at Group Centroids		
	1	2	1	2	Object	1	2
AP	-0.041	0.225	0.736	0.259	1.00	-0.303	-1.158
IN	0.437	0.470	0.477	0.023	2.00	3.746	0.683
MO	0.330	0.296	0.449	0.022	3.00	-1.173	1.362
HI	0.051	-0.061	0.319	-0.290			
FS	-0.403	0.822	0.305	0.201			
BI	0.660	0.167	0.230	0.072			
SHs	-0.209	-0.501	0.126	0.037			
SHf	0.385	0.097	-0.296	0.697			
HW	-0.070	-0.612	0.162	-0.259			

D. Classification Results

	Predicted Group Membership						
	Food Ball		Food Tube		Social		
Object Introduced	(N)	%	(N)	%	(N)	%	Total (N)
Food Ball	80	100.0	0	0	0	0	80
Food Tube	6	25.0	18	75.0	0	0	24
Social	18	32.1	0	0	38	67.9	56

Comparison of Habituation of State and Event Behaviors Between Trials

Food Ball

There was a significant difference in both duration and occurrence of the behaviors patterns occurring during the food ball trials ($p=0.000$, Table 15, 16, and 17). During the first food ball trials nearly all of the behaviors were elicited (Figure 12). By the second and following trials, the predatory behaviors (mainly bite) dropped out and the monitors seemed to exhibit more exploratory (APob) behaviors and continued to exhibit more of the play like behaviors (snout nudge and fore scrape) than predatory (bite) (Figure 12 and 13). The monitors seemed to learn that the prey within the ball could not be attained or ingested and adjusted their responses accordingly.

The monitors continued to interact with the food ball, even though they learned they could not retrieve prey. This pattern is consistent with the many studies and discussions concerning predatory behavior and play. The main studies concerning the relationship between these two categories of behavior have been on domestic cats, *Felis silvestris*. One study showed, through a series of physiological and behavioral experiments, that feline predatory behavior seems to be on a continuum from avoidance (the larger the prey) through play to killing (Pellis 1988). More recently the motivation, specifically hunger, for increased predatory behavior was linked with an increase in play behavior with a prey-like object (Hall 1998). If the monitor is physiologically capable of play, as discussed in Section II, then it is possible that these animals can also exhibit predatory play behavior as is suggested by the Black-throated monitor behavior patterns.

Food Tube

By the third trial, the interaction with the food tube increased in both duration and occurrence (Figure 14). During the first food tube trials predatory behaviors were elicited. The main changes over the three trials were in fore scrape and head insert behaviors (Figure 13). These behaviors most likely increased due to an increase in proficiency by the monitors of both attaining and ingesting prey as discussed below. The fore scraping behavior was utilized to open the hinged doors, then the monitors would insert their head into the tube in order to attain and ingest the prey inside the tube.

Social

By the fourth social trial, the interaction with the conspecific and container increased in both duration and occurrence. The main behaviors that showed a trend in change over the three trials was the approach object, **AP**, behavior (Figure 15 and 16). The monitors had low duration and occurrences of approach in the first three trials. However, by the fourth trial, the monitors increased both the time spent and frequency of approaching the conspecific. This behavior and trend seem to represent the avoidance mentioned earlier and may be a byproduct of the large size of this object. Due to the size of the introduced enclosure, the monitors did not have much room to move around their home enclosure and therefore could

Table 15. Ordered Repeated Measures Multivariate Tests for Occurrence of Behaviors Among Food Ball Trials. (**FS**)Fore scrape, (**BI**) Bite, (**MG**)Mouth grab, (**SN**)Snout Nudge, (**HI**) Head Insert, (**AP**)Approach Object, (**IN**)Interact, (**MO**)Move Object.

Effect	Wilk's Lambda	F	Hypothesis df	Error df	Sig.
Trial*	0.010	4.095	195.00	1332.081	0.000

Table 16. Univariate Tests (Between-Subjects) for Occurrence of Event Behaviors Involving the Object Among Trials. Abbreviations as in Table 15.

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig
Object Intro*	FS*	75445.674	2	5029.712	4.283	**0.000**
	BI*	13561.028	2	904.069	8.595	**0.000**
	MG*	1561.951	2	104.130	5.129	**0.000**
	HW*	56070.780	2	3738.052	5.476	**0.000**
	SN*	11120.504	2	741.367	3.741	**0.000**
	HI*	593.481	2	39.565	16.557	**0.000**
	AP*	1764.790	2	117.653	5.914	**0.000**
	IN*	3596.735	2	239.782	9.190	**0.000**
	MO*	801.782	2	53.452	5.869	**0.000**
Error	FS*	169090.270	150	1174.238		
	BI*	15146.466	150	105.184		
	MG*	2923.493	150	20.302		
	HW*	98291.195	150	682.578		
	SN*	28534.471	150	198.156		
	HI*	344.119	150	2.390		
	AP*	2864.585	150	19.893		
	IN*	3757.165	150	26.091		
	MO*	1311.412	150	9.107		

Table 17. Ordered Repeated Measures Multivariate Tests for Duration of Behaviors Among Food Ball Trials. (**HI**) Head Insert, (**AP**)Approach Object, (**IN**)Interact, (**MO**)Move Object.

Effect	Wilk's Lambda	F	Hypothesis df	Error df	Sig.
Trial*	0.092	5.592	80.00	538.924	0.000

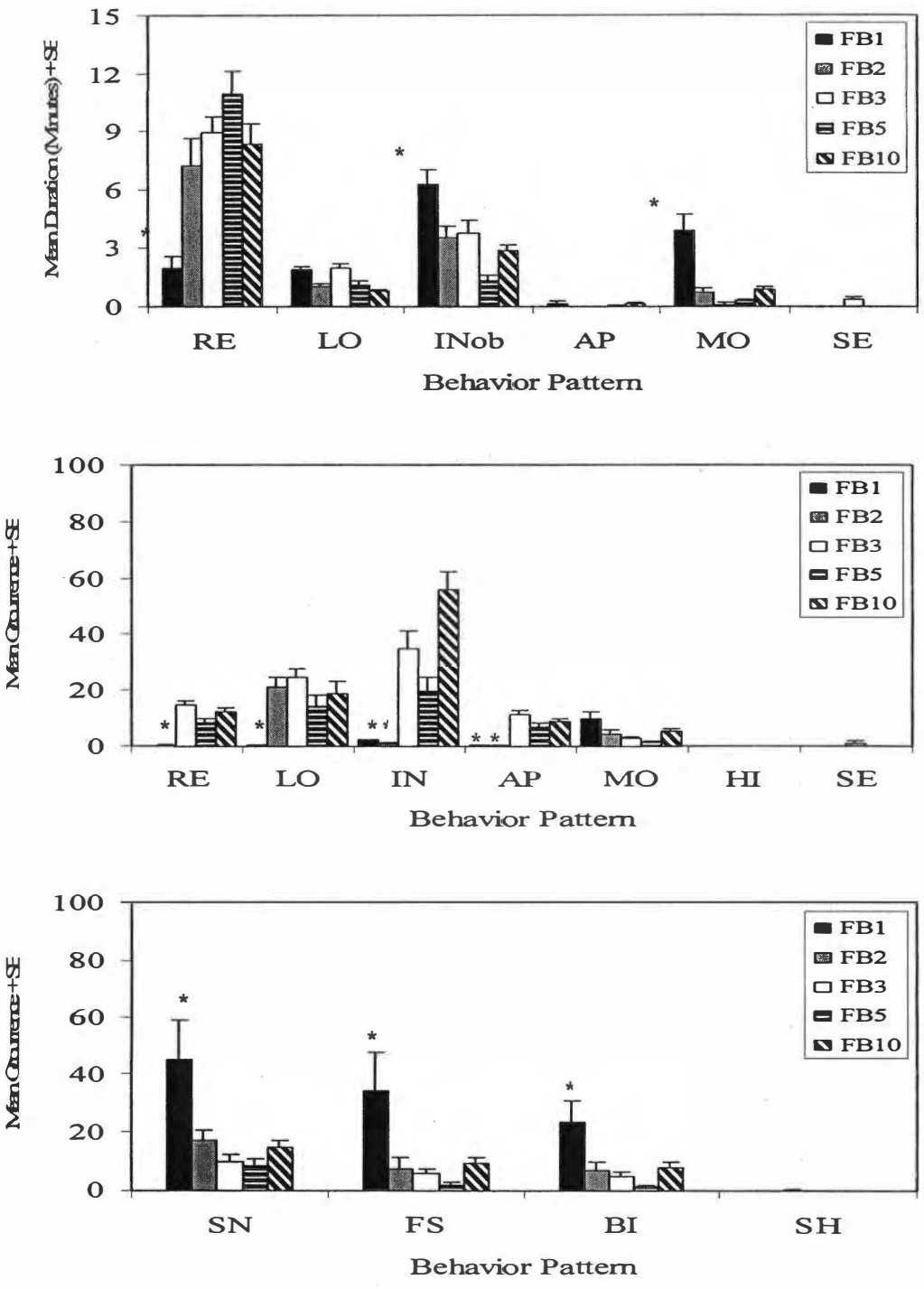


Figure 12. Mean Duration (Minutes) of State (Top) and Occurrence of State (Middle) and Event (Bottom) Behavior Patterns of the 8 Black-throated Monitors Involving the Object in 15-Min Introductions of the 1st Food Ball, 2nd Food Ball, 3rd Food Ball, 5th Food Ball, and 10th Food Ball Trials. Abbreviations of Behavior Patterns as in Figure 5. Significant differences ($p<0.05$) indicated by *.

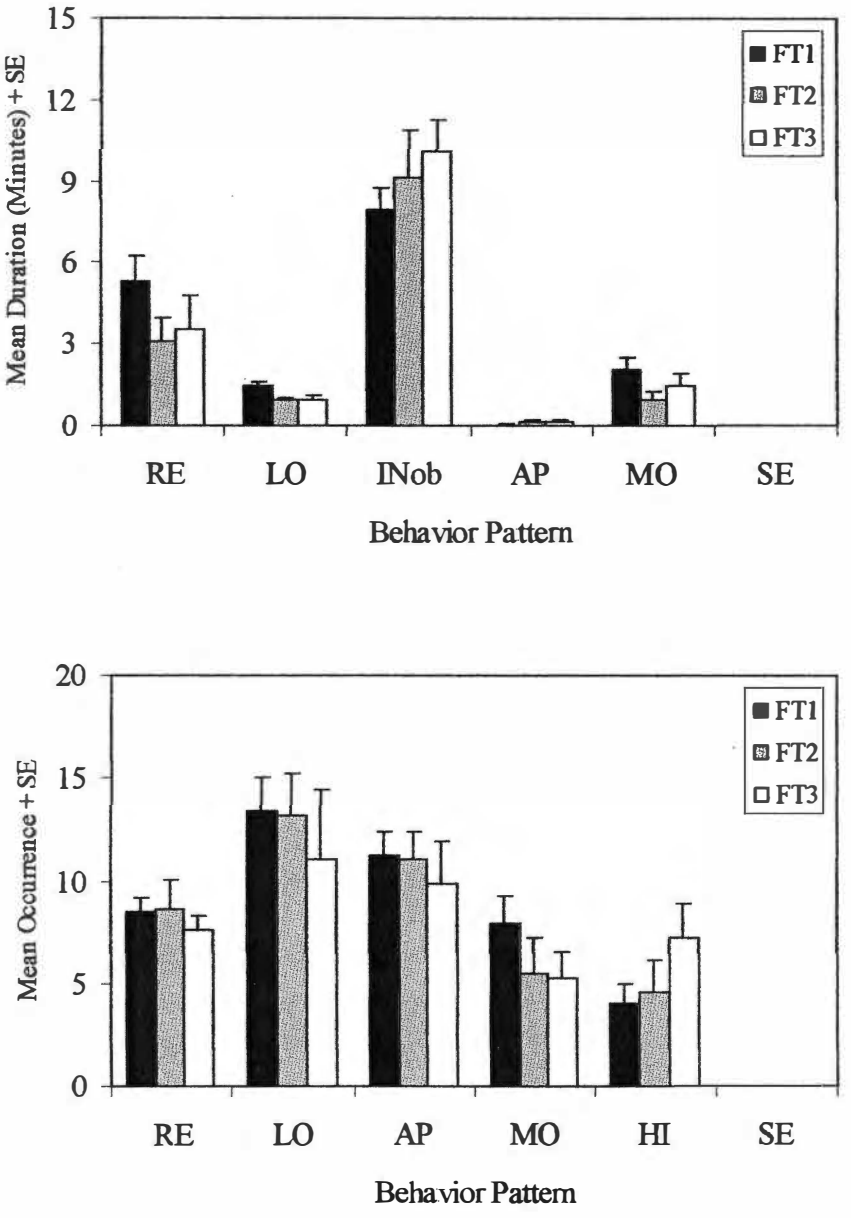


Figure 13. Mean Duration (Top) and Occurrence (Bottom) of State Behavior Patterns of the 8 Black-throated Monitors in the 15-Min Introductions of the 1st Food Tube, 2nd Food Tube, and 3rd Food Tube Trials. Abbreviations of Behavior Patterns as in Figure 5. No specific significant differences found.

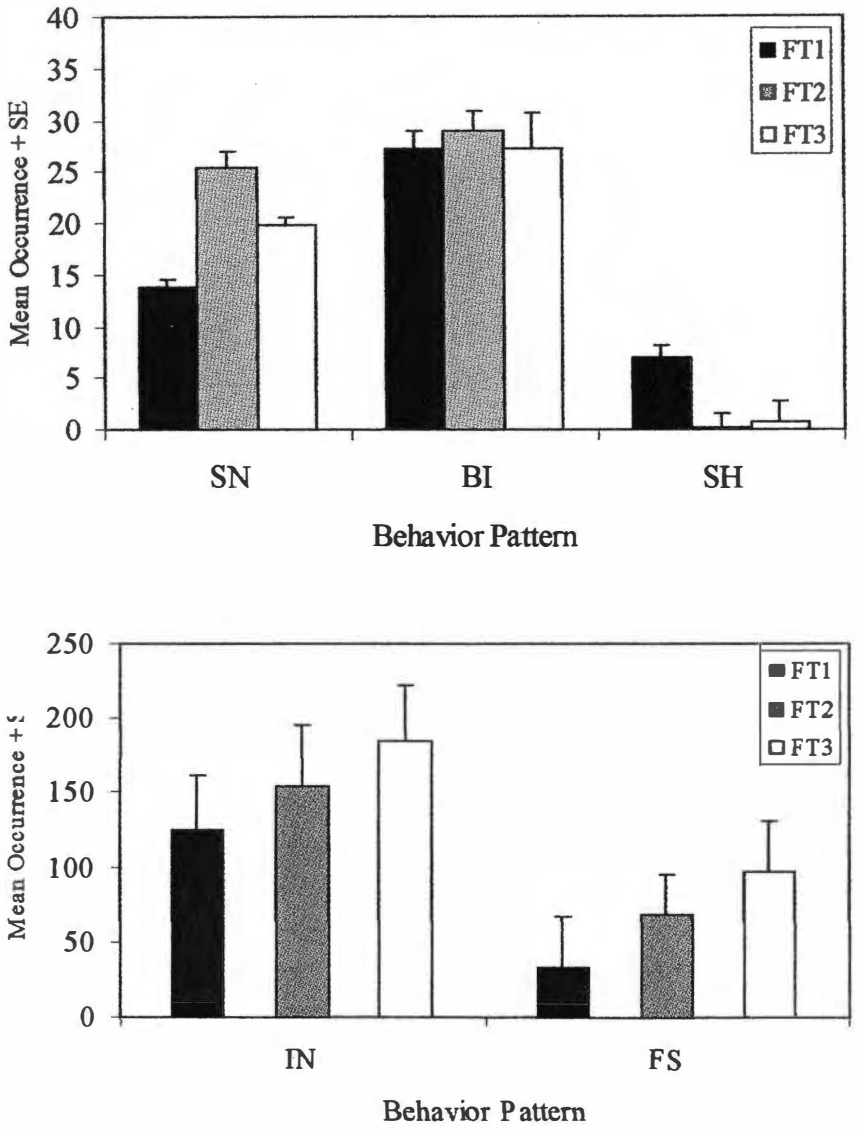


Figure 14. Mean Occurrence of Interaction (IN) Event (Top) and Most Frequent State and Event (Bottom) Behavior Patterns of the 8 Black-throated Monitors in the 15-Min Introductions of the 1st Food Tube, 2nd Food Tube, and 3rd Food Tube Trials. Abbreviations of Behavior Patterns as in Figure 5. No specific significant differences found.

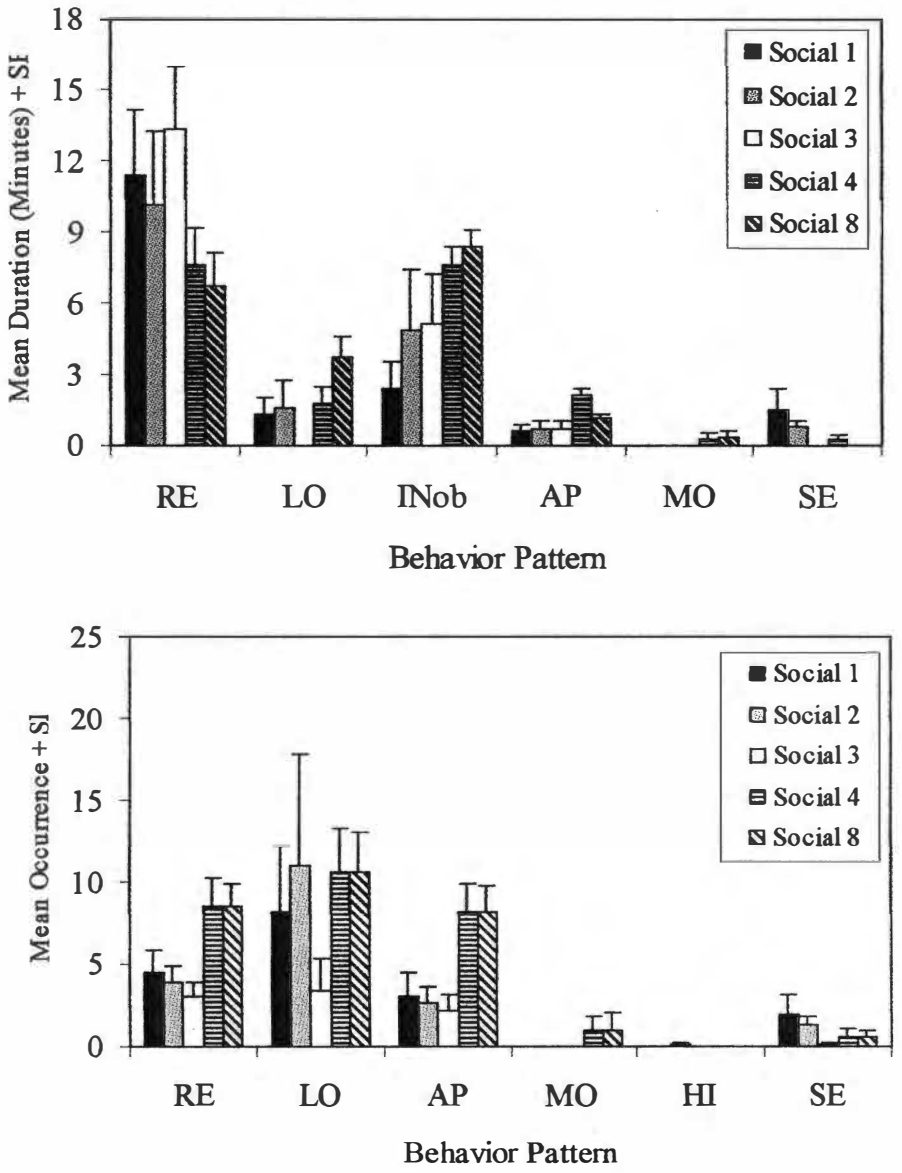


Figure 15. Mean Duration (Top) and Occurrence (Bottom) of State Behavior Patterns of the 8 Black-throated Monitors in the 15-Min Introductions of the 1st Social, 2nd Social, 3rd Social, 4th Social, and 8th Social Trials. Abbreviations of Behavior Patterns as in Figure 5. No specific significant differences found.

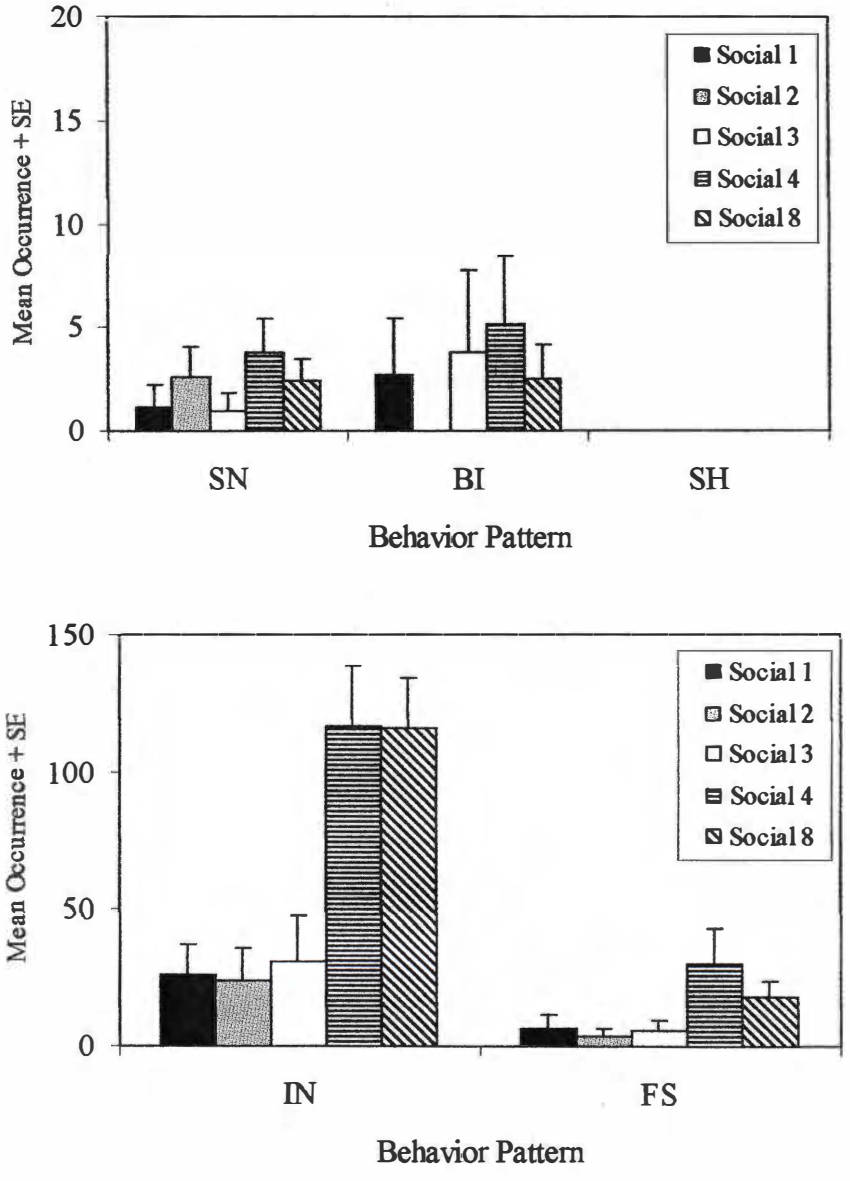


Figure 16. Mean Occurrence of Interaction (IN) Event (Top) and Most Frequent State and Event (Bottom) Behavior Patterns of the 8 Black-throated Monitors in the 15-Min Introductions of the 1st Social, 2nd Social, 3rd Social, 4th Social, and 8th Social Trials. Abbreviations of Behavior Patterns as in Figure 5. No specific significant differences found.

not choose to separate themselves from the stimulus as easily as they could with the food ball and food tube. It may have taken longer for the monitors to get used to this object.

Rates of Tongue Flicking Across, Between, and Within Trials

Across Trials

Overall tongue flick counts were also compared. The trend seen in the comparison of the other behaviors was also evident in the overall tongue flick data. There were significant differences between the objects introduced ($p=0.000$ Wilk's Lambda and LSD Table 4, Appedix Table A-4b) and the number of tongue flicks elicited. During the food tube trials, there were significantly fewer tongue flicks ($p=0.000$ LSD Appendix Table A-4b) emitted as compared to the food ball and social trials (Figure 17, Appendix Table A-4b). This was probably related to the increased duration and occurrence of moving the object (**MO**) (Figure 11) as compared to the other trials (Appendix, Table A-4). During this behavior, the monitor was moving the food tube with its mouth and therefore not able to emit any tongue flicks. The social stimuli elicited significantly more tongue flicks ($p=0.000$ LSD Figure 17, Appendix A-4b) than the food ball.

Between

The mean tongue flick occurrence was also compared over time. The trend observed in the food ball trials, as seen in Figure 18, was that the monitors seemed to be less active with each successive trial. The food tube trials, however, did not show a similar trend (Figure 19). There did not seem to be a change in the overall activity with each successive trial. The social trials, unlike the food ball or food tube, showed an increase in activity, i.e. number of tongue flicks, over time (Figure 20). These comparisons further support the hypothesis that the monitors reacted differently in response to each of the stimuli introduced.

Within Trials

The tongue flick data was also compared over 2 minute intervals within the trials. The two minute intervals where not significantly different when all were compared to each other in an ordered repeated MANOVA. However, there was an increase during the first interval of introduction (at 4 minutes) after which the tongue flicking remained at a constant rate. Finally this stabilization was followed by a decrease of tongue flicks which to near the baseline rate (as seen in the first two minute, pre-introduction, and interval) after the object was removed. Though the number of tongue flicks were not significantly different overall across all intervals, a closer look did show a significant difference among objects in some of the intervals during the introduction.

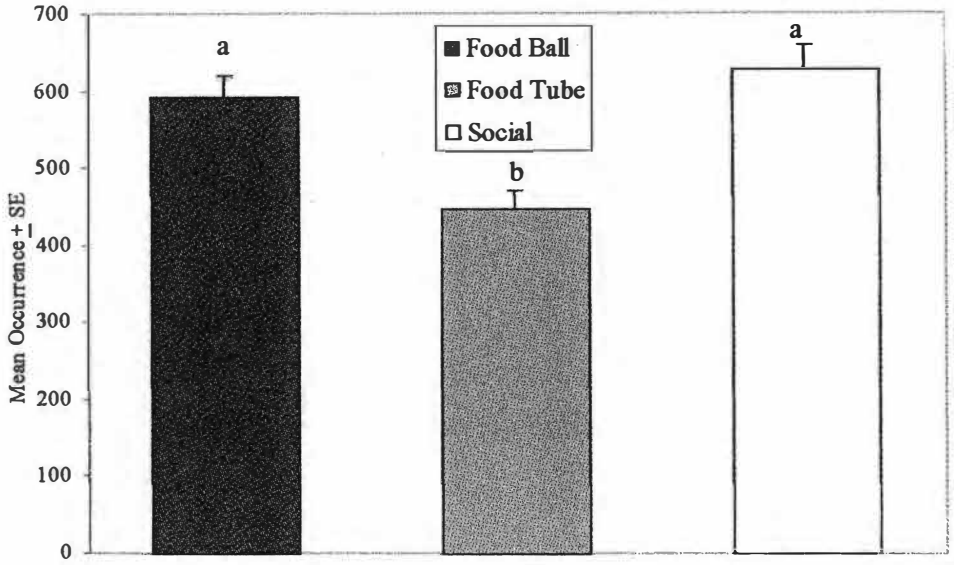


Figure 17. Mean Occurrence of Tongue Flicks of the 8 Black-throated Monitors in all 15-Min Introductions of the Food Ball (N=10), Food Tube (N=3), and Social (N=7) Stimuli. Significant differences ($p<0.05$) indicated by letters.

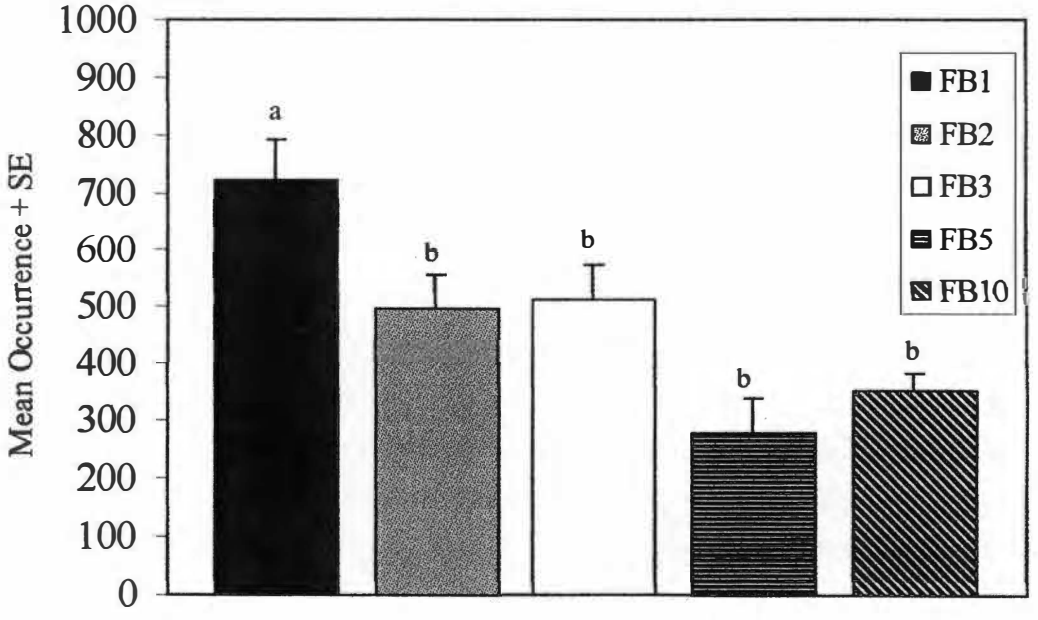


Figure 18. Mean Occurrence of Tongue Flicks of the 8 Black-throated Monitors in all 15-Min Introductions of the 1st Food Ball, 2nd Food Ball, 3rd Food Ball, 5th Food Ball, and 10th Food Ball Trials. Significant differences ($p<0.05$) indicated by letters.

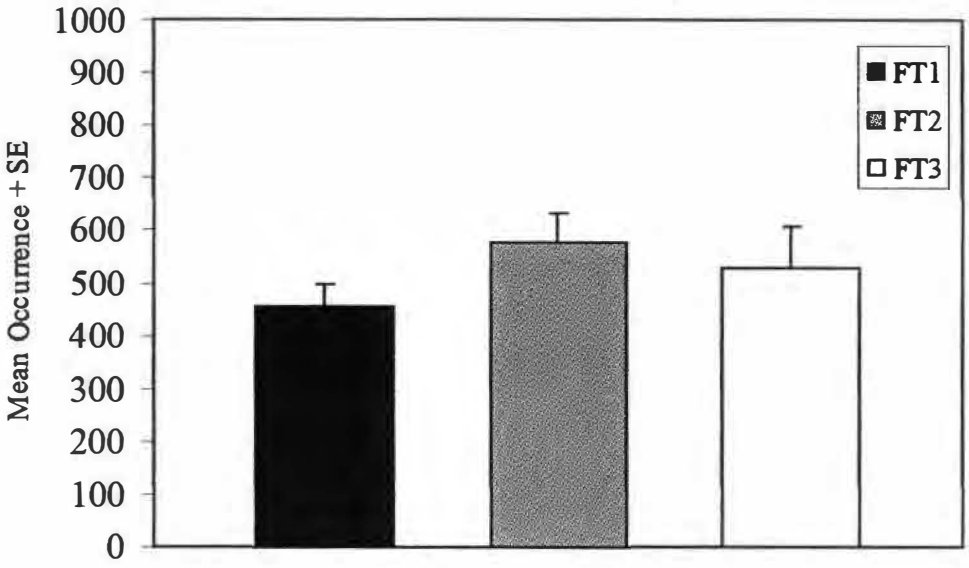


Figure 19. Mean Occurrence of Tongue Flicks of the 8 Black-throated Monitors in all 15-Min Introductions of the 1st Food Tube, 2nd Food Tube, and 3rd Food Tube Trials. No specific significant differences found.

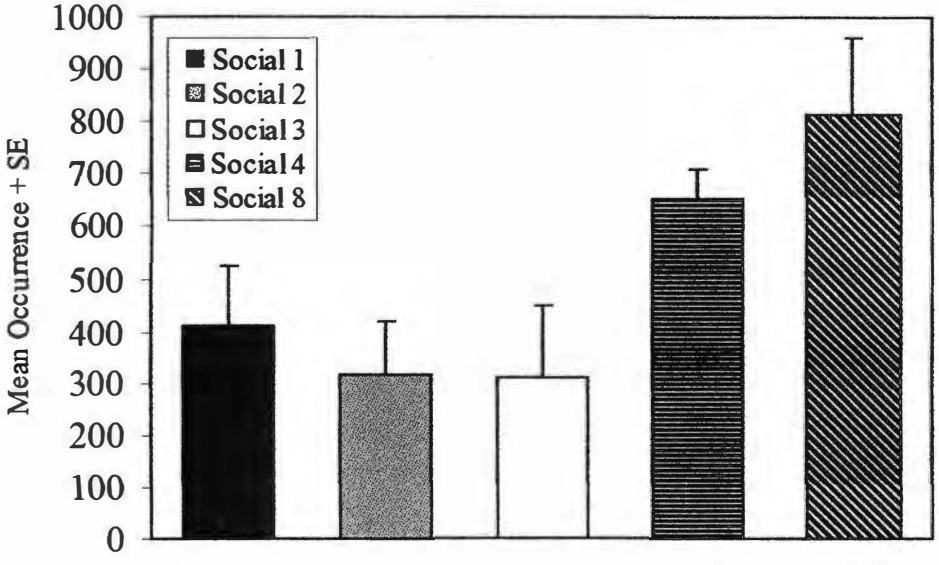


Figure 20. Mean Occurrence of Tongue Flicks of the 8 Black-throated Monitors in all 15-Min Introductions of the 1st Social, 2nd Social, 3rd Social, 4th Social, and 8th Social Trials. No specific significant differences found.

However, when comparing the intervals one by one, several were found to be significantly different among the different objects introduced (Figure 20, Table 18). The significant differences occurred in the first half of the trials. Most of the differences were seen in the comparison of the food ball and social trials ($p<0.011$ LSD, Appendix Table A-7). During the beginning of the introductions, at four minute, six minute, and eight minute intervals, there were significant differences. During the four minute interval, the food ball had significantly more tongue flicks. While during the six minute interval, the social trial had significantly more tongue flicks as compared to the food ball trials. Finally, in the eight minute interval, the food ball trials had significantly more tongue flicks as compared to the social trials. The food tube trials were significantly different later in the introductions ($p<0.039$ LSD, Appendix Table A-7). In the fourteen, twenty, twenty-two, twenty-four, and twenty-six minute intervals the food tube trials had significantly less tongue flicks as compared to the social (fourteen minute interval) and food ball (twenty, twenty-two, twenty-four, and twenty-six minute intervals) trials.

Just as there was not much difference seen among the social trials among the behaviors elicited, a similar trend and average occurrence of tongue flicks occurred (Figure 20). This lack of change over time could, again, be due to the very nature of the social trials. Though the shape of the object was similar each time, a new individual was presented in each trial. Thus these trials might not be expected to show much, if any, habituation. The slight spikes after the removal of the object is again due to the nature of these trials. As mentioned earlier, the social trials had more instances of tail swipes, or defensive/aggressive action, than any of the other trials. This posture and subsequent behavior was directed toward both the individual introduced as well as the keeper's hand at the instant of removal. This seems to suggest that these trials were stressful for the animals and therefore after or directly before an aggressive/defensive display they may have increased the number of tongue flicks elicited.

Food Ball

The tongue flick data within the trials was also compared over successive trials for each stimulus (Figure 21). In the food ball trials, there did seem to be trend to decrease tongue flicking after the first trial in the 6 minute through the 18 minute intervals when comparing the first, second and third food ball trials (Figure 22). Overall, the monitors' behaviors and overall activity level did seem to change overtime when comparing the first, second and third trials.

Food Tube

The number of tongue flicks in two-minute intervals over the entire trial was also compared among the food tube trials (Figure 23). There did seem to be a trend when comparing all of the 2 minute intervals among the third food tube and the first and second trials. There was a trend of drastic decrease in general activity level, i.e. number of tongue flicks, by the second food tube trial. Overall, the monitors'

Table 18. Univariate Tests (Between-Subjects) of Occurrence of Tongue Flicks During the Object Introductions Over Two Minute Intervals.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig
Object Intro	4 minute*	7061.375	2	3530.687	3.560	0.031
	6 minute	222.720	2	111.360	0.042	0.958
	8 minute*	23690.008	2	11845.004	4.705	0.010
	10 minute*	67033.191	2	33516.596	11.185	0.000
	12 minute*	35870.727	2	17935.363	6.562	0.002
	14 minute	6845.341	2	3422.670	1.692	0.188
	16 minute	12518.544	2	6259.272	2.883	0.059
	18 minute	9536.787	2	4768.394	2.450	0.090
	20 minute	5321.283	2	2660.641	1.814	0.167

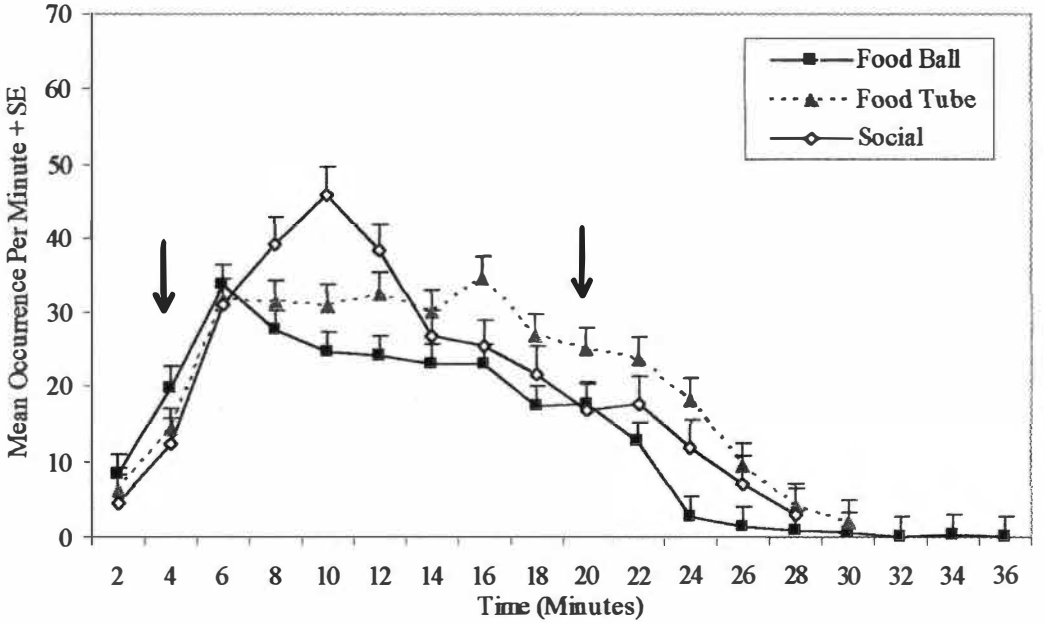


Figure 21. Mean Occurrence (Per Minute) of Tongue Flicks of each of the 8 Black-throated Monitors within 2-Min Intervals in the Baseline (0-5 Min, First Arrow), Object Present (5-20 Min), and Post Trial (20-30 Min, Second Arrow) Periods in Food Ball (N=10), Food Tube (N=3), and Social (N=7) Trials.

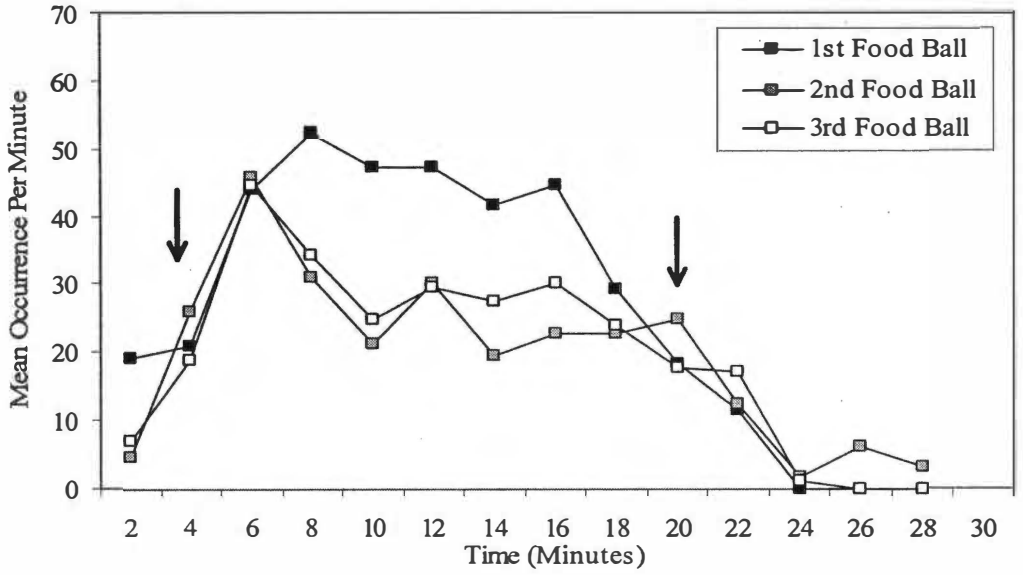


Figure 22. Mean Occurrence (Per Minute) of Tongue Flicks of the 8 Black-throated Monitors within 2-Min Intervals in the Baseline (0-5 Min, First Arrow), Object Present (5-20 Min), and Post Trial (20-30 Min, Second Arrow) Periods in the 1st Food Ball, 2nd Food Ball, and 3rd Food Ball Trials.

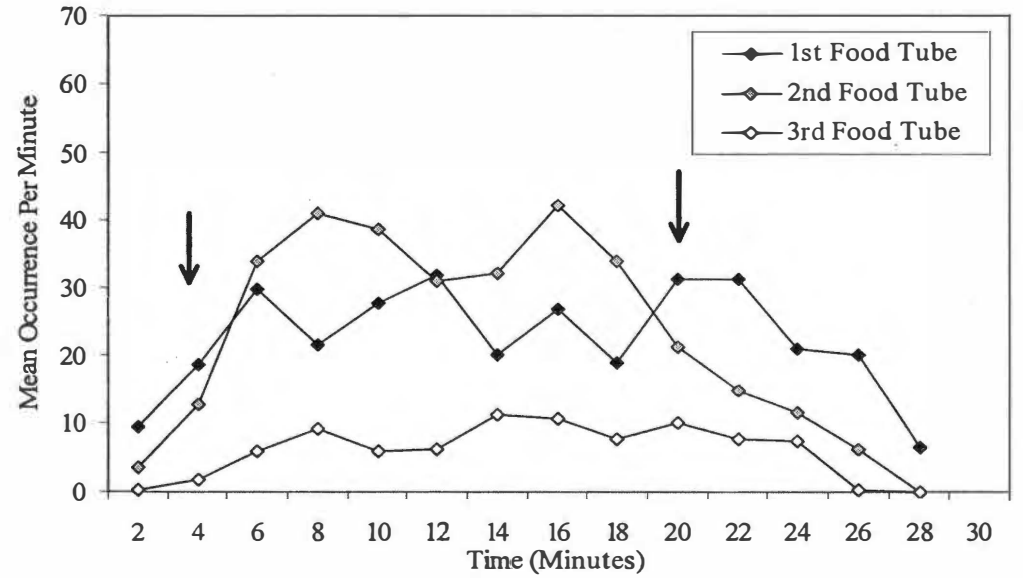


Figure 23. Mean Occurrence (Per Minute) of Tongue Flicks of the 8 Black-throated Monitors within 2-Min Intervals in the Baseline (0-5 Min, First Arrow), Object Present (5-20 Min), and Post Trial (20-30 Min, Second Arrow) Periods in the 1st Food Tube, 2nd Food Tube, and 3rd Food Tube Trials.

behaviors and overall activity level did seem to change overtime when comparing the first, second, and third food tube trials.

Social

There did not seem to be an overall trend when comparing all of the 2 minute intervals among the first, second, and third social trials (Figure 24). However by the third social trial, the overall activity decreased drastically in the six and eight minute intervals compared to the first and second trials. The third social trial had increased activity levels in the sixteen, eighteen, twenty, twenty-second, and twenty-four minute intervals, compared to the second trial. Overall, the monitors' behaviors and overall activity level did not consistently and drastically change overtime when comparing the first, second, and third social trials.

Learning in Food Tube Trials

Hypothesis Six: *The Black-throated monitors would attain and capture the prey in the food tube more quickly over time.*

It was hypothesized that behavior in the food ball trials would change more over time as compared to the food tube trials. In the food ball trials, there is evident habituation, or decrease in activity, by the third trial, as compared to the first trial (Figure 22). This seems to suggest that these animals did learn that the prey could not be obtained during the first trial. With this experience, there was just not as much interest and therefore less activity seen in the second and third trials.

Although the frequency (but not the duration) of interaction (**IN**) increased over the three food tube trials, the ability of the monitors to both attain entry to the tube and also capture the prey within the food tube were also evaluated. As the trials progressed, the monitors became more proficient at getting the hinged doors of the food tube open and pulling out and consuming the prey inside. This means, over time (by the third trial), that there was less time spent locomoting and searching for the object (Figure 13).

In these trials, the main form of measuring habituation and learning was through latency to head insertion into the tube and to capture the prey. The differences of both of these measures combined among the three food tube trials, was not found to be significant in an ordered repeated measures MANOVA. However when compared separately, there were significant differences found in each of these measures among the food tube trials ($p<0.035$ LSD, Table 19 and 20). To further investigate the monitors' reaction to the food tube, the latency to the first head insert (**HI**) was examined. Overall, the head insertion occurred quicker in the second and third trials as compared to the first food tube trials and this difference was significant in the univariate tests ($p=0.027$ LSD, Table 21, Figure 25). This result suggests that by the second trial, the monitors had learned to open the hinged doors quicker.

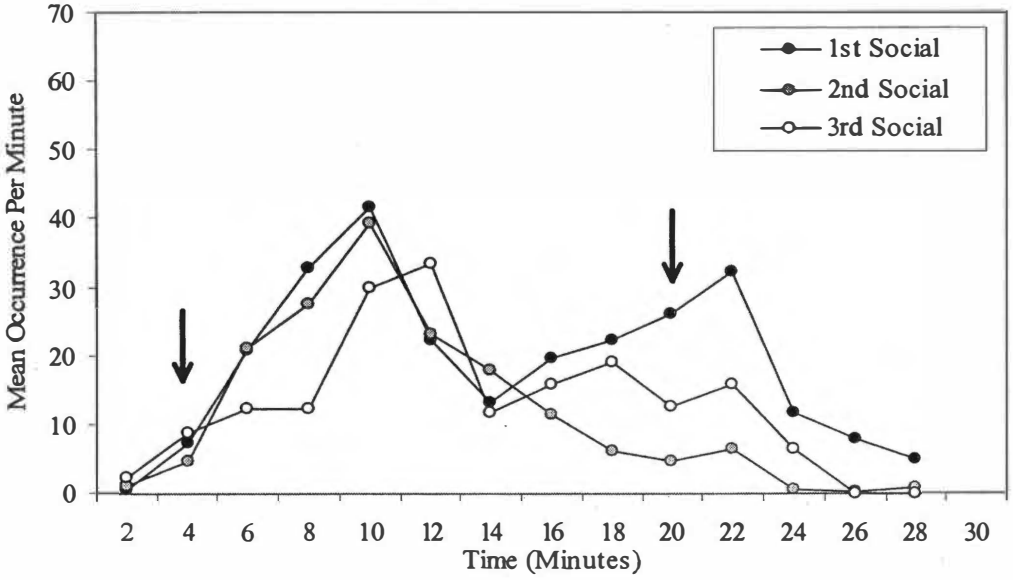


Figure 24. Mean Occurrence (Per Minute) of Tongue Flicks of the 8 Black-throated Monitors within 2-Min Intervals in the Baseline (0-5 Min, First Arrow), Object Present (5-20 Min), and Post Trial (20-30 Min, Second Arrow) Periods in 1st Social, 2nd Social, and 3rd Social Trials.

Table 19. Univariate Tests (Between-Subjects) of Latency to Head Insert and Capture in Food Tube Trials.

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	HI*	299100.228	2	149550.114	4.316	**0.035**
	CP*	81.543	2	40.772	3.941	**0.027**
Intercept	HI*	3602463.615	1	3602463.615	103.969	**0.000**
	CP*	636.254	1	636.254	61.494	**0.000**
FT Trial	HI*	299100.228	2	40.772	3.941	**0.035**
	CP*	81.543	2	149550.114	4.316	**0.027**
Error	HI	727636.608	21	34649.362		
	CP	217.279	21	10.347		

Table 20. Pairwise Comparison of Latency to Head Insert and Capture in Food Tube Trials. Only significant results reported.

Dependent Var	(I) FT Trial	(J) FT Trial	Mean Difference (I-J)	Std. Error	Sig
HI*	FT 1*	FT2*	225.009	93.072	**0.025**
		FT3*	247.076	93.072	**0.015**
CP*	FT 1*	FT2*	3.737	1.608	**0.030**
		FT3*	4.063	1.608	**0.020**

Table 21. Latency (in Minutes) to First Head Insertion into Food Tube in Black-throated Monitor Trials.

Individual	1st Food Tube	2nd Food Tube	3rd Food Tube	Average for Individual
F611	2.42	3.73	1.99	2.71
612	2.36	1.81	1.48	1.88
M613	6.44	1.92	2.43	3.60
M614	4.92	2.11	1.69	2.91
M615	2.09	1.62	1.69	1.80
618	3.27	2.49	1.71	2.49
621	3.68	1.95	3.47	3.03
F622	2.39	1.96	2.14	2.16
Average Per Trial	**3.45**	**2.20**	**2.07**	**2.57**
Standard Error	**0.52**	**0.09**	**0.23**	**0.22**

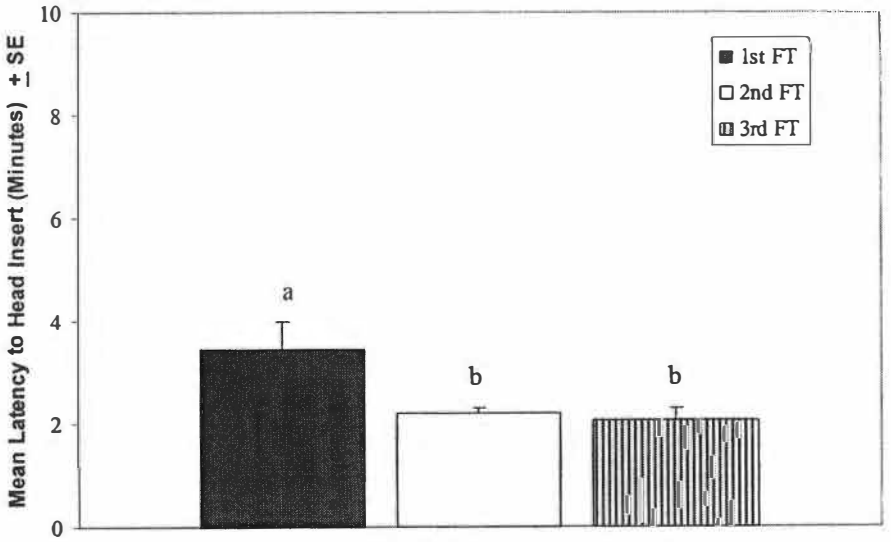


Figure 25. Mean Latency per Individual per Trial to Head Insertion in the 1st Food Tube, 2nd Food Tube, and 3rd Food Tube Black-throated Monitor Trials. Significant differences ($p<0.05$) indicated by letters.

It was found that there was a similar trend, though more dramatic, in the prey capture as compared to the head insertion. As seen in Figure 26, the first food tube trial had the longest mean latency to capture and this difference was significant when comparing the second and third trials ($p<0.030$ LSD, Table 22, Figure 26). The second and third were much shorter then the first, though there was not much difference between the last two trials (Table 22). However, this drastic decrease in the time it took any one individual to capture the prey in the object does demonstrate that these animals became better at attaining the prey. Comparing these two measures, the trend seems to be that the monitors were able to learn to both open and insert their head into the food tube and become more proficient at catching and consuming the prey inside.

During the first few trials, it was observed that the monitors were actually less active then they were in response to the food ball (all ten of which were conducted before the three food tube trials). This was probably due to the large size of the food tube compared to the food ball. The interaction, once the fear of novelty decreased, was similar to the food ball, consisting of fore scrape (**FS**) and bite (**BI**). However, with each successive trial, the monitors became more proficient at attaining and consuming the prey (Table 20 and 22). By the second trial, the monitors became much more proficient at **FS** and **BI** at the hinged doors to open the object, attain, and capture prey, **CP** (Figure 24). In the third set of trials, the individuals **IG** within the first five minutes and then began grabbing the food tube by the open doors and moving it around the enclosure, if they interacted with the tube at all.

Individual Differences

In order to identify any individuals that may be outliers as well as document individual variability, individual differences were evaluated. They were expected to be minimal as all eight individuals were from the same clutch and were raised in an identical manner. There were no significant differences among the individuals when comparing all of the durations and frequencies of the general behaviors. Only in the univariate (between-subject effects) analysis did locomotion show a significant difference ($p=0.002$ Wilk's Lambda LSD, Table 23) in the occurrence of some of the specific locomotion behaviors.

The data were graphed and the individuals were grouped by those of known and unknown sex. This was to investigate whether any gender differences could be observed. There does not seem to be any gender differences in the food ball trial interactions. There were similar results found in the food tube and social trials. There were a few specific behavior differences though, mainly in individuals 614 (Male), 615 (Male), and 622 (Female). However, these differences could be due to chance. When the general behaviors were broken down into the specific behaviors for interaction with the object and general locomotion, there was a significant difference overall among the individuals in both occurrence and duration of these behaviors. The individual reactions were also compared among the specific locomotion behaviors. The locomotion differences, however, did not have a general trend and involved more than the

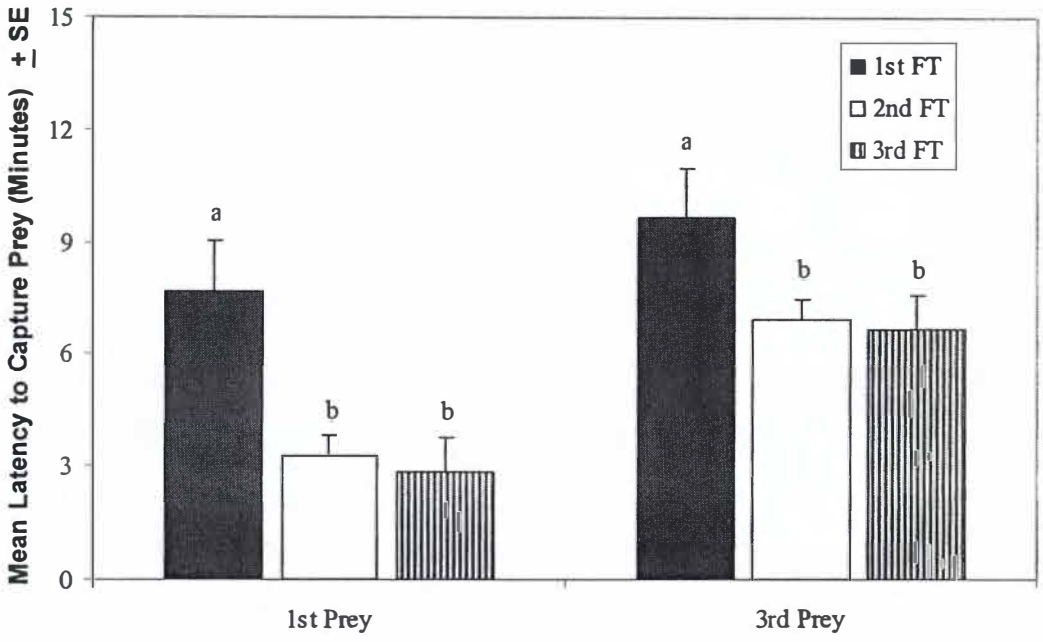


Figure 26. Mean Latency per Individual per Trial to Capture 1st and 3rd Prey in the 1st Food Tube, 2nd Food Tube, and 3rd Food Tube Black-throated Monitor Trials. Significant differences ($p<0.05$) indicated by letters.

Table 22. AverageTime (in Minutes) to 1st Capture of Each Prey During Food Tube Black-throated Monitor Trials.

	1st FT			2nd FT			3rd FT			
Individual	**1st Prey**	**2nd Prey**	**3rd Prey**	**1st Prey**	**2nd Prey**	**3rd Prey**	**1st Prey**	**2nd Prey**	**3rd Prey**	**Average for Individual**
F611	12.68	16.19	17.45	10.43	11.83	13.44	3.87	4.61	5.17	28.63
612.00	5.08	5.94	6.27	4.35	5.09	5.21	3.28	3.43	6.15	11.74
M613	12.76	15.47	18.16	4.75	10.55	10.82	6.15	6.96	10.06	26.22
M614	13.36	13.59	14.07	5.39	6.37	11.96	3.87	4.00	8.32	22.87
M615	5.23	6.19	6.89	3.87	4.37	5.22	3.50	3.90	4.37	11.76
618.00	11.67	11.93	12.37	3.85	6.30	7.85	3.86	14.74	16.34	19.28
621.00	10.75	11.10	11.39	4.57	4.71	6.05	9.11	9.61	10.59	19.22
F622	6.18	6.49	6.77	4.86	5.69	10.77	5.11	5.31	8.16	15.29
Average Per Trial	**9.71**	**10.86**	**11.67**	**5.26**	**6.87**	**8.91**	**4.84**	**6.57**	**8.65**	**19.38**
Standard Error	**1.20**	**1.28**	**1.47**	**0.20**	**0.69**	**0.95**	**0.68**	**1.34**	**1.26**	**1.80**

Table 23. Multivariate Tests of Event Locomotion Behaviors Among Individuals.

Effect	Wilk's Lambda	F	Hypothesis df	Error df	Sig.
Intercept	0.290	34.535	10.0	141.000	0.000
Individual*	0.597	1.815	42.0	655.42	0.002

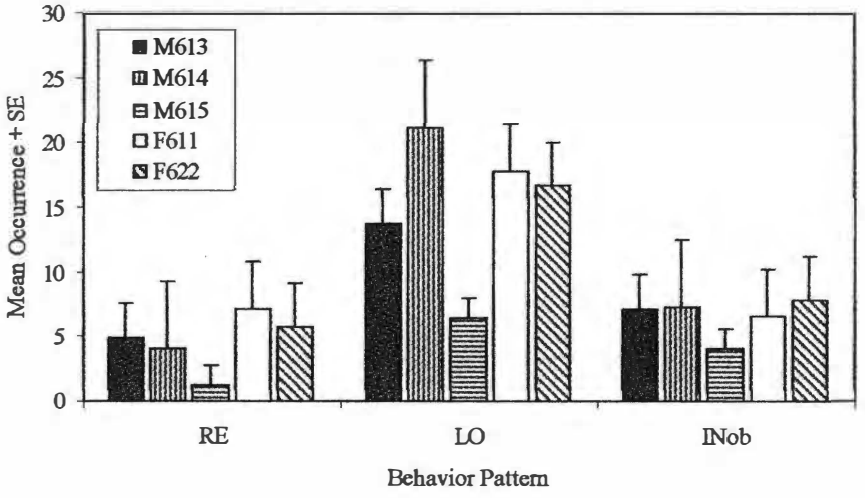
Table 24. Univariate Tests (Between-Subjects) for Event Locomotion Behaviors Among Individuals. Abbreviations as in Table 8.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig
Individual*	WA*	1070.875	7	152.982	2.655	**0.013**
	WU*	59.175	7	8.454	2.155	**0.041**
	EH*	271.744	7	38.821	2.394	**0.024**
	EV*	164.494	7	23.499	2.823	**0.009**
	TS*	14.294	7	2.042	2.563	**0.016**

three individuals mentioned above. There was no specific significance among individuals and the occurrence of any one of the specific locomotion behaviors.

However, there was overall significant difference among walk, walk up, tail swipe, escape horizontally, and escape vertically ($p<0.041$ LSD, Table 24, Figure 27). Similar trends were seen as in the grouped behavior analysis for the interaction with the object. However, the specific analysis of the locomotion behaviors showed more intricate relationships and differences among the individuals and the behaviors that the trials elicited.

M614 seemed to be more active in the general sense, more reactive to the social introductions, and less likely to approach the object than some of the other individuals. However, male 614 did spend more time interacting than most of the other monitors. M615 was much less active in both general and towards the object than many of the other individuals. F622 showed more time spent active (as seen by tongue flicks, licks) than most individuals. Overall, the individuals varied, though they did not vary enough to be significant. All of the analyses were calculated per individual in order to further compensate for individual differences. This was so that no one individual would skew the data and give a false picture of the overall monitor reaction to a particular situation.



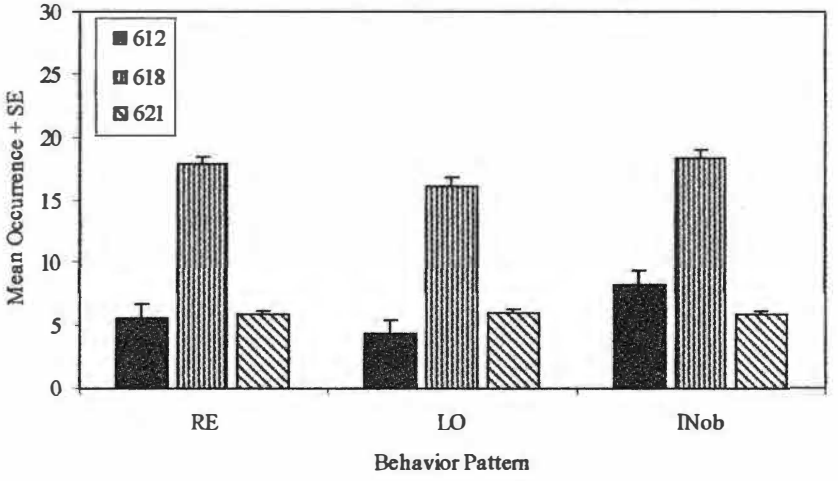


Figure 27. Mean Occurrence of Behaviors Observed Per Trial in Food Ball (N=10) Black-throated Monitor Trials For each Individual of Known Sex (A) and of Unknown Sex (B). Similar trends were seen in both Food Tube and Social trials.

SECTION V: CONCLUSIONS

This study explored the responses of 8 Black-throated monitors to three types of object enrichment in a zoo setting. All animals were housed and tested in an identical fashion. It was expected that the Black-throated monitors would elicit different behavior patterns in response to two different objects containing prey as well as a social stimulus. The food ball was a plastic ball containing live mice that the monitors could see and smell, but not attain. The food tube was a plastic tube with hinged doors containing live mice that the monitors could see, smell, capture, and ingest. Finally, in the social stimulus the monitors could not have physical contact with, but could see and smell, a conspecific. It was also expected that exploratory and play behavior would be observed and quantified. These data established that exploratory, predatory, and social behaviors occurred in the presence of the introduced stimuli. Play behavior was more difficult to discern due to the presence of prey in both object treatments. Overall the null hypothesis that there would be no difference in the monitors' responses to each stimulus, was rejected.

Specifically, these analyses suggested that the food ball, though the same prey was presented in the food tube, elicited different responses from the lizards than did the food tube. The lizards spent the most time interacting with the food ball. The monitors exhibited more exploratory behavior, represented by the duration of approach object behavior and occurrence of locomotion, than with the other objects. (Figures 10 and 11). The monitors also continued to interact with the food ball, even though they learned they could not retrieve the prey. This pattern is consistent with the many studies and discussions concerning predatory behavior and play (Pellis 1998). However, compared to the food tube trials, the monitors seemed to be overall more active (Figure 19) as seen by tongue flicks and exploratory behaviors in the food ball trials.

The Black-throated monitors discriminated between the food tube, where the prey could be eaten, and the food ball, where the prey was inaccessible. The food tube elicited the most occurrences of snout nudge, fore scrape, bite, and shake. While the food ball seemed to elicit more exploratory and play-like behaviors and increased bouts of interaction with the object, the food tube elicited mostly predatory behaviors and increased time spent though fewer overall bouts of interaction with the object (Figure 10 and 11). Although there were few behaviors performed exclusively in either the food ball or food tube trials, the frequency and occurrence varied. These differences could have been due to variation in size, type, and ease in manipulation. For example, the head insert object could only occur in the food tube trials and the monitors were more apt to fore scrape in the food tube trials to open the hinged doors.

The social trials were very similar to the food ball in the time spent and number of times the various behaviors were elicited. However, there were a few behaviors that only occurred in the social trials. The conspecific introductions elicited seesaw and head wipe behaviors not seen in the other treatments. These behaviors are social behaviors and were directed at the conspecific.

The different behaviors elicited were also compared in a discriminate analysis and were found to predict the type of stimulus presented (Tables 13 and 14). The monitors not only differed in the behaviors elicited among the object trials, but also differed in the amount of habituation both among and within the different trials. The food ball trials seemed to show a definite habituation trend, more so than the food tube and social. Through time, with each trial, the food ball elicited an increase in the number of locomotion, interaction, and approach object behaviors (Figure 12 and 13) from the lizards. There was a general increase in the overall object interaction in the food tube trials than in the other types of trials. The mean tongue flicks over time also showed a decrease in general activity by the second food ball trials. Throughout time, over the three trials, the food tube elicited increased time spent interacting and increased occurrences of head insert and all behaviors involving the object (Figure 14). Unlike the food ball and food tube introductions, the social stimuli, over the eight trials, elicited similar behaviors and the monitors actually increased their interaction with the conspecific over time.

The monitors also showed a learning ability in the food tube trials. The head insertion and mean time to capture the prey were compared and both behaviors were performed more quickly with each trial. The monitors learned to solve the problem of attaining the prey through the hinged doors of the tube. Finally, it was expected that the eight individuals, from the same clutch, would not differ significantly in their responses to the different objects and this assumption was supported through statistical analyses.

There were some design flaws within the experimental protocol. Though each individual received the same number of trials for each condition, this study was not balanced in number of trials across conditions. The Black-throated monitor trials also lacked control objects within the enriched trials, i.e., there was never a trial with only the objects, without prey or social stimulus, to further explore the base interest of the monitors' in the objects themselves. Finally, this study also lacked a systematic format for the size or structure of the objects, thus increasing the difficulty in deciphering what elements of the study were responsible for the animals' behaviors. Despite these disadvantages, these experiments resulted in a quantitative intensive analysis of 8 individuals and their responses to various object introductions. Through these observations an ethogram was created and a comprehensive study of this varanid's behavior was conducted. This study can be used to design more scientific and comparative studies concerning the behavior of squamate reptiles and the possible benefits of enrichment, specifically object introductions, in these animals.

The object responses seen in captivity can lead us to reassess behavior reported in wild monitors as well as to look for more affiliative social behavior and novel foraging tactics. Most importantly, it has also been suggested that learning and experience may both be formative processes in wild populations and sources of problematic phenotypic plasticity and even taming in captive populations (Trut 1999) that can seriously compromise conservation and/or reintroduction efforts. This study demonstrated evidence of learning and habituation which could possibly be processes that could help or hurt conservation efforts depending on whether the animals are enriched or deprived in their captive environments. Serious

consideration should be given to the addition or improvement of enrichment, specifically object introduction in order to increase the activity level of captive squamate reptiles, specifically monitor lizards.

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APPENDIX

Table A-1. Details of Black-throated Monitor 611-614 Prey and Social Stimuli Trials.

A. F611

Date	Trial Number	Time Started	Individual in Trial	Object/Ind Introduced	Object Number
2/7/2001	**7**	2:01-4pm	F611	Food Ball	FB 1
2/26/2001	**13**	AM(8-11:59)	F611	612	Social 1
3/5/2001	**20**	12-2pm	F611	Food Ball	FB 2
3/12/2001	**35**	AM(8-11:59)	F611	Food Ball	FB 3
3/14/2001	**45**	12-2pm	F611	618	Social 3
3/21/2001	**52**	12-2pm	F611	Food Ball	FB 4
3/28/2001	**60**	12-2pm	F611	Food Ball	FB 5
4/2/2001	**68**	12-2pm	F611	Food Ball	FB 6
4/5/2001	**76**	12-2pm	F611	614	Social 4
4/17/2001	**83**	2:01-4pm	F611	Food Ball	FB 7
4/18/2001	**85**	AM(8-11:59)	F611	621	Social 5
4/30/2001	**98**	12-2pm	F611	Food Ball	FB 8
5/3/2001	**105**	12-2pm	F611	622	Social 6
5/9/2001	**111**	12-2pm	F611	Food Ball	FB 9
5/15/2001	**119**	12-2pm	F611	Food Ball	FB 10
5/17/2001	**126**	AM(8-11:59)	F611	613	Social 7
5/22/2001	**136**	12-2pm	F611	Food Tube	FT 1
5/30/2001	**142**	12-2pm	F611	Food Tube	FT 2
6/5/2001	**150**	12-2pm	F611	Food Tube	FT 3
6/7/2001	**157**	AM(8-11:59)	F611	615	Social 8

B. 612

Date	Trial Number	Time Started	Individual in Trial	Object/Ind Introduced	Object Number
2/7/2001	**6**	2:01-4pm	612	Food Ball	FB 1
3/5/2001	**23**	12-2pm	612	Food Ball	FB 2
3/7/2001	**30**	2:01-4pm	612	611	Social 2
3/12/2001	**38**	12-2pm	612	Food Ball	FB 3
3/14/2001	**43**	AM(8-11:59)	612	618	Social 3
3/21/2001	**51**	12-2pm	612	Food Ball	FB 4
3/28/2001	**59**	12-2pm	612	Food Ball	FB 5
4/2/2001	**67**	12-2pm	612	Food Ball	FB 6
4/5/2001	**74**	AM(8-11:59)	612	614	Social 4
4/17/2001	**82**	12-2pm	612	Food Ball	FB 7
4/18/2001	**87**	AM(8-11:59)	612	621	Social 5
4/30/2001	**97**	12-2pm	612	Food Ball	FB 8
5/3/2001	**104**	12-2pm	612	622	Social 6
5/9/2001	**114**	2:01-4pm	612	Food Ball	FB 9
5/15/2001	**122**	12-2pm	612	Food Ball	FB 10
5/17/2001	**125**	AM(8-11:59)	612	613	Social 7
5/22/2001	**135**	12-2pm	612	Food Tube	FT 1
5/30/2001	**145**	12-2pm	612	Food Tube	FT 2
6/5/2001	**153**	2:01-4pm	612	Food Tube	FT 3
6/7/2001	**160**	12-2pm	612	615	Social 8

Table A-1. Continued.

C. M613

Date	Trial Number	Time Started	Individual in Trial	Object/Ind Introduced	Object Number
2/7/2001	3	12-2pm	M613	Food Ball	FB 1
2/26/2001	10	AM(8-11:59)	M613	612	Social 1
3/5/2001	16	AM(8-11:59)	M613	Food Ball	FB 2
3/7/2001	24	AM(8-11:59)	M613	611	Social 2
3/12/2001	31	AM(8-11:59)	M613	Food Ball	FB 3
3/14/2001	41	AM(8-11:59)	M613	618	Social 3
3/21/2001	49	AM(8-11:59)	M613	Food Ball	FB 4
3/28/2001	56	AM(8-11:59)	M613	Food Ball	FB 5
4/2/2001	65	AM(8-11:59)	M613	Food Ball	FB 6
4/5/2001	72	AM(8-11:59)	M613	614	Social 4
4/17/2001	79	AM(8-11:59)	M613	Food Ball	FB 7
4/18/2001	88	AM(8-11:59)	M613	621	Social 5
4/30/2001	95	AM(8-11:59)	M613	Food Ball	FB 8
5/3/2001	101	AM(8-11:59)	M613	622	Social 6
5/9/2001	108	AM(8-11:59)	M613	Food Ball	FB 9
5/15/2001	116	AM(8-11:59)	M613	Food Ball	FB 10
5/22/2001	132	AM(8-11:59)	M613	Food Tube	FT 1
5/30/2001	139	AM(8-11:59)	M613	Food Tube	FT 2
6/5/2001	146	AM(8-11:59)	M613	Food Tube	FT 3
6/7/2001	154	AM(8-11:59)	M613	615	Social 8

D. M614

Date	Trial Number	Time Started	Individual in Trial	Object/Ind Introduced	Object Number
2/7/2001	1	AM(8-11:59)	M614	Food Ball	FB 1
2/26/2001	12	AM(8-11:59)	M614	612	Social 1
3/5/2001	18	AM(8-11:59)	M614	Food Ball	FB 2
3/7/2001	26	AM(8-11:59)	M614	611	Social 2
3/12/2001	34	AM(8-11:59)	M614	Food Ball	FB 3
3/14/2001	39	AM(8-11:59)	M614	618	Social 3
3/21/2001	46	AM(8-11:59)	M614	Food Ball	FB 4
3/28/2001	55	AM(8-11:59)	M614	Food Ball	FB 5
4/2/2001	63	AM(8-11:59)	M614	Food Ball	FB 6
4/17/2001	77	AM(8-11:59)	M614	Food Ball	FB 7
4/18/2001	91	2:01-4pm	M614	621	Social 5
4/30/2001	93	AM(8-11:59)	M614	Food Ball	FB 8
5/3/2001	100	AM(8-11:59)	M614	622	Social 6
5/9/2001	109	AM(8-11:59)	M614	Food Ball	FB 9
5/15/2001	117	AM(8-11:59)	M614	Food Ball	FB 10
5/17/2001	129	12-2pm	M614	613	Social 7
5/22/2001	130	AM(8-11:59)	M614	Food Tube	FT 1
5/30/2001	141	AM(8-11:59)	M614	Food Tube	FT 2
6/5/2001	149	12-2pm	M614	Food Tube	FT 3
6/7/2001	156	AM(8-11:59)	M614	615	Social 8

Table A-2. Details of Black-throated Monitor 615, 618, 621-22 Prey and Social Stimuli Trials.

A. M615

Date	Trial Number	Time Started	Individual in Trial	Object/Ind Introduced	Object Number
2/7/2001	**4**	12-2pm	M615	Food Ball	FB 1
2/26/2001	**9**	AM(8-11:59)	M615	612	Social 1
3/5/2001	**17**	AM(8-11:59)	M615	Food Ball	FB 2
3/7/2001	**25**	AM(8-11:59)	M615	611	Social 2
3/12/2001	**32**	AM(8-11:59)	M615	Food Ball	FB 3
3/14/2001	**42**	AM(8-11:59)	M615	618	Social 3
3/21/2001	**48**	AM(8-11:59)	M615	Food Ball	FB 4
3/28/2001	**57**	AM(8-11:59)	M615	Food Ball	FB 5
4/2/2001	**64**	AM(8-11:59)	M615	Food Ball	FB 6
4/5/2001	**71**	AM(8-11:59)	M615	614	Social 4
4/17/2001	**80**	AM(8-11:59)	M615	Food Ball	FB 7
4/18/2001	**89**	12-2pm	M615	621	Social 5
4/30/2001	**94**	AM(8-11:59)	M615	Food Ball	FB 8
5/3/2001	**102**	AM(8-11:59)	M615	622	Social 6
5/9/2001	**107**	AM(8-11:59)	M615	Food Ball	FB 9
5/15/2001	**115**	AM(8-11:59)	M615	Food Ball	FB 10
5/17/2001	**123**	AM(8-11:59)	M615	613	Social 7
5/22/2001	**133**	AM(8-11:59)	M615	Food Tube	FT 1
5/30/2001	**138**	AM(8-11:59)	M615	Food Tube	FT 2
6/5/2001	**147**	AM(8-11:59)	M615	Food Tube	FT 3

B. 618

Date	Trial Number	Time Started	Individual in Trial	Object/Ind Introduced	Object Number
2/7/2001	**8**	2:01-4pm	618	Food Ball	FB 1
2/26/2001	**14**	AM(8-11:59)	618	612	Social 1
3/5/2001	**21**	12-2pm	618	Food Ball	FB 2
3/7/2001	**28**	12-2pm	618	611	Social 2
3/12/2001	**36**	12-2pm	618	Food Ball	FB 3
3/21/2001	**53**	12-2pm	618	Food Ball	FB 4
3/28/2001	**61**	12-2pm	618	Food Ball	FB 5
4/2/2001	**69**	12-2pm	618	Food Ball	FB 6
4/5/2001	**75**	12-2pm	618	614	Social 4
4/17/2001	**84**	2:01-4pm	618	Food Ball	FB 7
4/18/2001	**86**	AM(8-11:59)	618	621	Social 5
4/30/2001	**99**	12-2pm	618	Food Ball	FB 8
5/3/2001	**106**	12-2pm	618	622	Social 6
5/9/2001	**112**	2:01-4pm	618	Food Ball	FB 9
5/15/2001	**120**	12-2pm	618	Food Ball	FB 10
5/17/2001	**127**	AM(8-11:59)	618	613	Social 7
5/22/2001	**137**	12-2pm	618	Food Tube	FT 1
5/30/2001	**143**	12-2pm	618	Food Tube	FT 2
6/5/2001	**151**	12-2pm	618	Food Tube	FT 3
6/7/2001	**158**	12-2pm	618	615	Social 8

Table A-2. Continued.

C. 621

Date	Trial Number	Time Started	Individual in Trial	Object/Ind Introduced	Object Number
2/7/2001	5	12-2pm	621	Food Ball	FB 1
2/26/2001	15	12-2pm	621	612	Social 1
3/5/2001	22	12-2pm	621	Food Ball	FB 2
3/7/2001	29	2:01-4pm	621	611	Social 2
3/12/2001	37	12-2pm	621	Food Ball	FB 3
3/14/2001	44	12-2pm	621	618	Social 3
3/21/2001	50	12-2pm	621	Food Ball	FB 4
3/28/2001	58	AM(8-11:59)	621	Food Ball	FB 5
4/2/2001	66	12-2pm	621	Food Ball	FB 6
4/5/2001	73	AM(8-11:59)	621	614	Social 4
4/17/2001	81	12-2pm	621	Food Ball	FB 7
4/30/2001	96	12-2pm	621	Food Ball	FB 8
5/3/2001	103	AM(8-11:59)	621	622	Social 6
5/9/2001	113	2:01-4pm	621	Food Ball	FB 9
5/15/2001	121	12-2pm	621	Food Ball	FB 10
5/17/2001	124	AM(8-11:59)	621	613	Social 7
5/22/2001	134	12-2pm	621	Food Tube	FT 1
5/30/2001	144	12-2pm	621	Food Tube	FT 2
6/5/2001	152	12-2pm	621	Food Tube	FT 3
6/7/2001	159	12-2pm	621	615	Social 8

D. F622

Date	Trial Number	Time Started	Individual in Trial	Object/Ind Introduced	Object Number
2/7/2001	2	12-2pm	F622	Food Ball	FB 1
2/26/2001	11	AM(8-11:59)	F622	612	Social 1
3/5/2001	19	AM(8-11:59)	F622	Food Ball	FB 2
3/7/2001	27	AM(8-11:59)	F622	611	Social 2
3/12/2001	33	AM(8-11:59)	F622	Food Ball	FB 3
3/14/2001	40	AM(8-11:59)	F622	618	Social 3
3/21/2001	47	AM(8-11:59)	F622	Food Ball	FB 4
3/28/2001	54	AM(8-11:59)	F622	Food Ball	FB 5
4/2/2001	62	AM(8-11:59)	F622	Food Ball	FB 6
4/5/2001	70	AM(8-11:59)	F622	614	Social 4
4/17/2001	78	AM(8-11:59)	F622	Food Ball	FB 7
4/18/2001	90	12-2pm	F622	621	Social 5
4/30/2001	92	AM(8-11:59)	F622	Food Ball	FB 8
5/9/2001	110	AM(8-11:59)	F622	Food Ball	FB 9
5/15/2001	118	AM(8-11:59)	F622	Food Ball	FB 10
5/17/2001	128	12-2pm	F622	613	Social 7
5/22/2001	131	AM(8-11:59)	F622	Food Tube	FT 1
5/30/2001	140	AM(8-11:59)	F622	Food Tube	FT 2
6/5/2001	148	12-2pm	F622	Food Tube	FT 3
6/7/2001	155	AM(8-11:59)	F622	615	Social 8

Table A-3. Pairwise Comparisons of Durations of Interaction Behaviors. **(HI)** Head Insert, **(IN)** Interact, **(MO)** Move object

Dependent Variable	Object Intro (I)	Object Intro (J)	Mean Diff (I-J)	Std. Error	Sig.
HI	Food Ball	Food Tube*	-9.636	0.836	**0.000**
		Social	-0.004	0.626	0.995
	Food Tube*	Social*	9.632	0.876	**0.000**
IN	Food Ball*	Food Tube*	-25.084	3.395	**0.000**
		Social*	-20.285	2.541	**0.000**
	Food Tube	Social	4.799	3.558	0.179
MO	Food Ball*	Food Tube*	-3.416	1.538	0.028
		Social*	4.170	1.151	**0.000**
	Food Tube*	Social*	7.587	1.612	**0.000**

Table A-4. Pairwise Comparisons of Occurrences of Interaction Behaviors.

A. (FS) Fore scrape, **(BI)** Bite, **(MG)** Mouth grab, **(SHs)**Shake slow, **(SHf)** Shake fast, **(HW)** Headwipe, **(SN)**Snout nudge, **(HI)**Head Insert, **(AP)**Approach Object, **(IN)**Interact

Dependent Variable	Object Intro (I)	Object Intro (J)	Mean Diff (I-J)	Std. Error	Sig.
FS	Food Ball	Food Tube*	-55.383	7.898	**0.000**
		Social	-8.318	5.913	0.162
	Food Tube*	Social*	47.065	8.280	**0.000**
BI*	Food Ball*	Food Tube*	-34.853	5.196	**0.000**
		Social*	-10.004	3.890	**0.010**
	Food Tube*	Social*	24.849	5.447	**0.000**
MG	Food Ball	Food Tube	-0.042	0.117	0.721
		Social*	0.190	0.087	**0.030**
	Food Tube	Social	0.232	0.122	0.059
SHs	Food Ball	Food Tube	0.043	0.087	0.619
		Social*	-0.185	0.065	**0.005**
	Food Tube	Social*	-0.228	0.091	**0.012**
SHf	Food Ball	Food Tube*	-1.088	0.085	**0.000**
		Social	0.032	0.064	0.622
	Food Tube*	Social*	1.119	0.089	**0.000**
HW	Food Ball*	Food Tube*	2.450	0.904	**0.007**
		Social*	3.813	0.677	**0.000**
	Food Tube	Social	1.363	0.948	0.151
SN	Food Ball	Food Tube	-0.338	1.018	0.740
		Social	-0.903	0.762	0.237
	Food Tube	Social	-0.565	1.067	0.596
HI	Food Ball	Food Tube*	-5.292	0.359	**0.000**
		Social	-0.018	0.269	0.947
	Food Tube*	Social*	-5.5.274	0.376	**0.000**
AP	Food Ball	Food Tube	-0.883	1.145	0.442
		Social*	3.986	0.857	**0.000**
	Food Tube	Social*	4.869	1.200	**0.000**
IN	Food Ball	Food Tube	-10.237	1.271	**0.000**
		Social	1.852	0.952	0.054
	Food Tube*	Social*	12.089	1.333	**0.000**

Table A-4. Continued.

B. (MO) Move Object, (TF) Tongue flick

Dependent Variable	Object Intro (I)	Object Intro (J)	Mean Diff (I-J)	Std. Error	Sig.
MO*	Food Ball*	Food Tube*	-2.358	0.715	**0.001**
		Social*	3.136	0.535	**0.000**
	Food Tube*	Social*	5.494	0.749	**0.000**
TF*	Food Ball*	Food Tube*	233.115	32.138	**0.000**
		Social*	73.161	9.4773	**0.000**
	Food Tube*	Social*	-159.955	22.654	**0.000**

Table A-5. Pairwise Comparisons of Durations of Locomotion Behaviors. (WA) Walk, (WU) WalkUp, (EH) Escape Horizontally, (EV) Escape Vertically

Dependent Variable	Object Intro (I)	Object Intro (J)	Mean Diff (I-J)	Std. Error	Sig.
WA	Food Ball*	Food Tube*	6.348	1.611	**0.000**
		Social*	8.780	1.225	**0.000**
	Food Tube	Social	2.431	1.689	0.152
WU	Food Ball*	Food Tube*	-6.12	0.274	**0.027**
		Social*	0.415	0.208	**0.048**
	Food Tube	Social	-0.196	0.287	0.496
EV	Food Ball	Food Tube	2.618	1.658	0.117
		Social*	4.962	1.260	**0.000**
	Food Tube	Social	2.344	1.737	0.179
EH	Food Ball*	Food Tube*	2.009	0.600	**0.001**
		Social*	1.584	0.456	**0.001**
	Food Tube	Social	-0.425	0.628	0.500

Table A-6. Pairwise Comparisons of Occurrence of Locomotion Behaviors. (WA) Walk, (WU) WalkUp, (EH) Escape Horizontally, (EV) Escape Vertically

Dependent Variable	Object Intro (I)	Object Intro (J)	Mean Diff (I-J)	Std. Error	Sig.
WA	Food Ball*	Food Tube*	6.429	1.767	**0.000**
		Social*	9.959	1.323	**0.000**
	Food Tube	Social	3.530	1.852	0.059
WU	Food Ball*	Food Tube*	1.254	0.461	**0.007**
		Social*	0.891	0.345	**0.011**
	Food Tube	Social	-0.363	0.483	0.454
EV	Food Ball*	Food Tube*	2.021	0.672	**0.003**
		Social*	1.652	0.503	**0.001**
	Food Tube	Social	-0.369	0.704	0.601
EH	Food Ball	Food Tube	1.733	0.937	0.066
		Social*	3.025	0.702	**0.000**
	Food Tube	Social	1.292	1.292	0.191
TS	Food Ball	Food Tube	-0.175	0.208	0.401
		Social*	-0.407	0.156	**0.010**
	Food Tube	Social	-0.232	0.218	0.288

Vita

Jennifer Diane Walton Manrod was born and raised in Knoxville, Tennessee on April 30, 1977. She went to grade school and high school at Farragut primary, intermediate, and high schools. She graduated from Farragut High School in 1995. From there, she went to Virginia Tech in Blacksburg, Virginia and received a B.S. in Biology in 1998. She then married Matthew Manrod in March 1999 and continued a career as a veterinary assistant in Easton, Maryland.

Jennifer then moved back to Tennessee and went to the University of Tennessee, Knoxville and earned a M.S. degree in Ecology and Evolutionary Biology with a minor in Statistics in 2003. She is currently working as a laboratory technician and is pursuing her teaching career as an adjunct professor at Pellissippi State Community College